

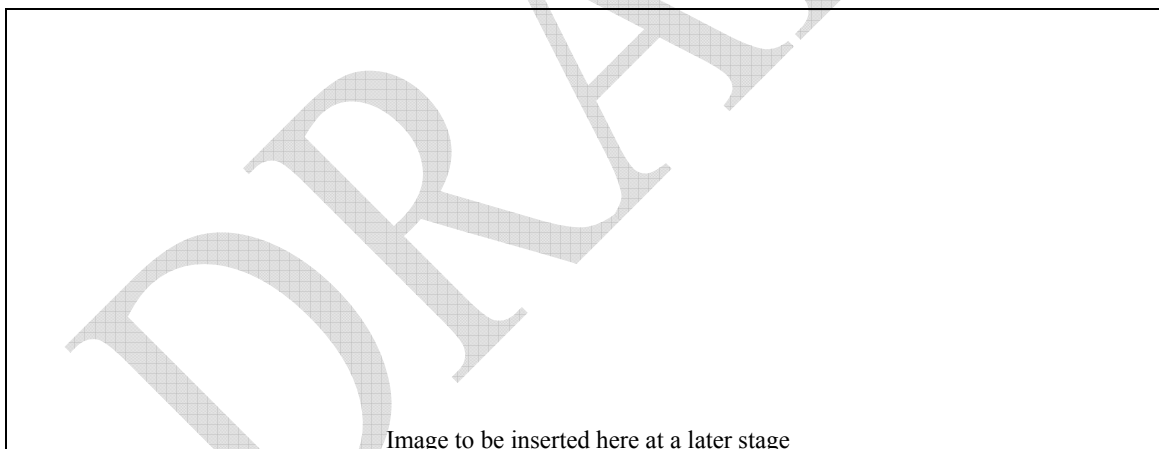
Common NOise ASSEssment MethOds in EU
(CNOSSOS-EU)

To be used by the EU Member States for strategic noise mapping after
adoption as specified in the Directive 2002/49/EC

Authorship list: *to be added at a later stage*

2011

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for providing

Technical technical advice to DG ENV related to the preparation and implementation of the common European noise assessment methods (CNOSSOS-EU) to be used for the purpose of strategic noise mapping after adoption as specified in the Directive 2002/49/EC (END).

NOTE:

This report has been prepared to serve as a scientific basis for the Commission's Implementing Act to amend Annex II of Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise in Europe.

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EXECUTIVE SUMMARY

In accordance with Art. 6.2 of the Environmental Noise Directive 2002/49/EC (END), the European Commission decided to develop **Common NOise aSSessment methOdS (CNOSSOS-EU)** for *road traffic, railway traffic, aircraft and industrial* noise to be used after adoption by the Member States for the purpose of strategic noise mapping as required by Article 7 of the END. The development of CNOSSOS-EU was co-ordinated by the Joint Research Centre's Institute of Health and Consumer Protection and performed in close liaison with the CNOSSOS-EU Technical Committee which was composed from experts nominated by the Member States and setup under the Regulatory Noise Committee. The overall work was performed in the context of two consecutive administrative arrangements stipulated between the Joint Research Centre and the Directorate General for Environment (DG ENV), namely NOISE-II (contract no. 070307/2008/511090) and NOISE-III (contract no. 070307/2009/549280).

This report forms the technical basis for amending Annex II of Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise in Europe via a Commission Implementing Decision in early 2012.

CNOSSOS-EU aims at improving the consistency and comparability of noise assessment results across the EU Member States, which are performed on the basis of the data becoming available through the consecutive rounds of noise mapping in Europe as required by the END.

The CNOSSOS-EU methodological framework described in this report is the fruit of an intensive and in-depth consultation, which involved a wide array of noise experts in two consecutive phases. The first and informal phase (March 2009 to May 2010) prepared the ground for the formal consultation and the technical development that were undertaken with the Member States during the second phase of the project (November 2010 to December 2011). The outcome of all events pertaining to both phases (i.e., Workshops, ad hoc technical meetings and meetings of the CNOSSOS-EU Technical Committee and its associated Working Groups) can be retrieved via the CIRCA web site of DG ENV (<http://circa.europa.eu/Public/irc/env/noisedir/library>)

This report describes the outcome of eight out of thirteen Working Groups (WGs) of the CNOSSOS-EU Technical Committee established under the Noise Regulatory Committee on 13 December 2010, namely:

WG 1 on “Quality Framework”; WG 2 on “Road traffic noise source emission”; WG 3 on “Railway traffic noise source emission”; WG 4 on “Aircraft noise prediction”; WG 5 “Sound propagation and industrial noise source emission”; WG 6 “Guidance for the competent use of CNOSSOS-EU” (conceptualisation of the guidance); WG 9 on “Revised Electronic Noise Data Reporting Mechanism” (ENDRM)¹ (conceptualisation of the revised ENDRM) and WG 10 on “Assigning noise levels and population to buildings”.

The outcome of these WGs constitute the core part of the CNOSSOS-EU methodological framework which will feed from a technical standpoint the legal text of the Implementing Act related to the amendment of Annex II of the Directive 2002/49/EC.

¹ The chapter on the “Revised Electronic Noise Data Reporting Mechanism” is under preparation by WG 9 co-ordinated by the European Environment Agency (EEA) and will be incorporated into the final draft version of the present report (planned for November/December 2011)

Four other WGs (plus the completed versions of the CNOSSOS-EU guidance and the EEA's revised ENDRM) pertain to the operational and implementation phase of CNOSSOS-EU (2012-2015) in the EU Member States and will be activated once the amendment of Annex II of the Directive will become effective. These WGs are the following:

WG 7 on "CNOSSOS-EU Database of input data"; WG 8 on "CNOSSOS-EU reference software"; WG 12 on "Pilot studies for CNOSSOS-EU validation" and WG 13 on "Help desk and Training of EU MS".

One last working group (WG 11) was established to liaise with the on-going activities on "Burden of disease estimation" which are co-ordinated by WHO-European Centre for Environment and Health. This will greatly help the burden of disease estimations due to environmental noise to get benefit from the noise exposure data gathered in the context of the planned rounds of strategic noise mapping in Europe.

The CNOSSOS-EU methodological framework at this stage will focus on the strategic noise mapping requirements and the objective is to have it operational in and implemented by the EU Member States starting from the 3rd round of strategic noise mapping in 2017.

In conclusion, the European Commission in close consultation with and the formal involvement of a wide array of technical expertise on noise from the EU Member States, and in close liaison with EEA and WHO has advanced the development of a consistent common noise assessment methodological framework in EU (CNOSSOS-EU) capable of providing comparable results from the strategic noise mapping carried out by the Member States to fulfil their obligations under the END.

The CNOSSOS-EU framework was developed taking into account the state of the art of scientific, technical and practical knowledge about assessment of environmental noise in Europe and optimised over the cost being incurred related to the retrieval of the required actual input data and to the undertaking of the periodic strategic noise mapping by the EU MS.

The European Commission, the European Environment Agency, WHO and the EU Member States aligned to the requirements of the END (art. 1.1) are intensifying their efforts for facing at best the big challenge and opportunity to:

- make available to the European citizens reliable info on the noise levels they are exposed to and the associated health implications;
- draw appropriate action plans for preventing and reducing exposure to harmful levels of noise.

ACKNOWLEDGEMENTS

Special recognition goes to the experts of the CNOSSOS-EU Technical Committee (nominated by the Member States and setup under the Noise Regulatory Committee) for providing their advice on a continuous basis throughout the development of the technical description of the CNOSSOS-EU framework and for acting as the review panel of the present report.

We are thankful to the members of the Noise Regulatory Committee for their critical comments on the CNOSSOS-EU process, for bringing forward the experience of the Member States related to the usage of existing noise assessment methods for strategic noise mapping and for their forward-looking ideas about the development of CNOSSOS-EU.

The contribution received from a wide array of noise experts involved during the preparatory phase of the CNOSSOS-EU development is greatly appreciated as it paved the way for the further development of CNOSSOS-EU which was undertaken during the second phase of the project under formal consultation with the Member States.

The efforts dedicated by the European Environment Agency and the WHO European Centre for Environment and Health to liaise their activities and establish synergies with CNOSSOS-EU, and to elaborate joint working plans on environmental noise with DG ENV and DG JRC are highly appreciated.

Last but not least, DG ENV (Directorate C “Sustainable Resources Management, Industry & Air”, Unit 3 “Industrial emissions, Air quality and Noise”) is gratefully acknowledged for the financial support of the overall CNOSSOS-EU process via the two consecutive administrative arrangements NOISE-II and NOISE-III stipulated with DG JRC and for steering the entire policy process related to the environmental noise file.

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This JRC Reference Report on CNOSSOS-EU is the fruit of contribution of and/or consultation with a wide array of noise experts from the EU Member States, European Commission services and close collaboration with EEA and WHO European Centre for Environment and Health. The following list of contributors pertains to both phases of development of CNOSSOS-EU and refers only to the actually running Working Group under the CNOSSOS-EU Technical Committee.

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Gianluca Memoli	NPL, UK
Dick Botteldooren	Gent University, BELGIUM
Lars Find Larsen	COWI, DENMARK
Matthew Burdett	Extrium, UK
Giovanni Brambilla	CNR, ITALY
Wolfgang Babisch	UBA, GERMANY
Marco Paviotti	Noise consultant - former JRC-IHCP member
Jurgita Lekaviciute	JRC-IHCP
Stylianos Kephelopoulos	JRC-IHCP

European Commission Services:

DG ENV:

Balazs. Gergely	DG ENV, Unit C.3
Joachim D'Eugenio	DG ENV, Unit C.3
Scott Breckett	DG ENV, Unit C.3
Thomas Verheye	DG ENV, Unit C.3, Acting HoU

DG MOVE:

Koen de Vos	DG MOVE
David Batchelor	DG MOVE

EEA:

Colin Nugent	European Environment Agency
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WHO-Europe:

Rokho Kim	WHO European Centre for Environment and Health
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Furthermore, a wide array of **noise experts** have been involved in the discussions during and after the workshops and the ad-hoc meetings organised and **contributed** to the recommendations made during the **preparatory phase** of development of CNOSSOS-EU.

◆ **Benchmark/Testing ad-hoc meeting on “Road traffic noise source and propagation”, 17-18 November 2009, Brussels**

- W. Bartolomaeus (BAST, Germany)
- M. Cerchiali (ARPAT Toscana, Italy)
- J. Defrance (CSTB, France)
- G. Dutilleux (CETE Est, France)
- E. Le Duc (SETRA, France)
- J. Lelong (INRETS, France)
- G. Licitra (ARPAT Toscana, Italy)
- R. Nota (DVS, The Netherlands)
- M. Paviotti (Noise consultant, Italy)
- B. Peeters (M+P, The Netherlands)
- B. Plovsing (Delta, Denmark)
- D. van Maercke (CSTB, France)
- H. Jonasson (Noise consultant, Sweden) (apologies)*
- L. Schade (UBA, Germany) (apologies)*

- S. Kephelopoulos (JRC-IHCP)
- F. Anfosso-Lédée (JRC-IHCP)
- G. Balazs (DG ENV)
- C. Nugent (EEA)

◆ **Ad hoc meeting on “Railway traffic noise”, 7 December 2009, Ispra**

M. Dittrich (TNO, The Netherlands)
H. Jonasson (Noise consultant, Sweden)
R. Jones (Noise consultant, United Kingdom)
F. Letourneaux (SNCF, France)
U. Moehler (Moehler & Partners, Germany)
M. Paviotti (Noise consultant, Italy)
T. Werst (EBA, Germany)
I Aspuru (LABLEIN, Spain) (apologies)
M. Beuving (DELTARAIL, The Netherlands) (apologies)
R. Ortner (Umweltbundesamt, Austria) (apologies)

S. Kephelopoulos (JRC-IHCP)
F. Anfosso-Lédée (JRC-IHCP)

◆ **Workshop on “Aircraft noise prediction”, 19-20 January 2010, Brussels**

D. Bergmans (NLR, The Netherlands)
L. Cavadini (EUROCONTROL, Int)
C. Damar (ACI EUROPE, Belgium)
P. de Vos (DHV, The Netherlands)
L. Ehnbohm (Swedish Transport Agency, Sweden)
I. Granoien (SINTEF ICT, Norway)
M. Hankenen (LFV Group, Sweden)
U. Isermann (DLR, Germany)
A. Kruger Dokter (NLR, The Netherlands)
R. Kucharski (Institute of Environmental Protection, Poland)
T. Leskelä (Ilmailulaitos Finavia, Finland)
K. H. Liasjø (Oslo Lufthavn AS, Norway)
A. Malige (DGAC/STAC, France)
M. Paviotti (Consultant, Italy)
M. Portier (To70 Consulting company, The Netherlands)
D. Rhodes (Civil Aviation Authority, United Kingdom)
S. Turner (Bureau Veritas (for Defra), United Kingdom)
N. Van Oosten (Anotec Consulting SL, Spain)
M. Viinikainen substituted by T. Leskelä (Finavia Corporation, Finland)
(apologies)
R. Girvin (FAA, USA) (apologies)

S. Kephelopoulos (JRC-IHCP)
F. Anfosso-Lédée (JRC-IHCP)
G. Balazs (DG ENV)
C. Nugent *(apologies)*
K. de Vos (DG TREN) *(present only the 1st day)*
H. Vu Duc (DG TREN) *(present only the 1st day)*
S. Arrowsmith (EASA)
W. Franken (EASA)

◆ **Ad-hoc meeting with software developers, 8-9 March 2010, Ispra**

K.G. Krapf (Wölfel Meßsysteme Software GmbH+Co, Germany)
W. Probst (Datakustik GmbH, Germany)
J. Schaal (Braunstein + Berndt GmbH, Germany)
H. Stapelfeldt (Stapelfeldt Ingenieurgesellschaft mbH, Germany)
H. van Leeuwen (DGMR consultants, The Netherlands)
D. van Maercke (CSTB, France)
D. Zollitsch (Braunstein + Berndt GmbH, Germany)
D. Manvell (Brüel & Kjaer, Denmark) (apologies)
C. Popp (Lärmkontor GmbH, Germany) (apologies)

N. Jones (Extrium, United Kingdom)
U. Moehler (Moehler + Partner, Germany)
M. Paviotti (Noise consultant, Italy)
S. Shilton (Acustica Ltd, United Kingdom)
T. Werst (EBA, Germany)
P. de Vos (DHV, The Netherlands) (apologies)

S. Kephelopoulos (JRC-IHCP)
F. Anfosso-Lédée (JRC-IHCP)
J. Lekaviciute (JRC-IHCP)
B. Gergely (DG ENV) (*apologies*)

◆ **Workshop on the "Selection of common noise assessment methods in EU",
8-9 September 2009, Brussels**

I. Aspuru(Labein, Spain)
A. Bäckman (Expert Panel on Noise, Sweden)
W. Bartolomaeus (BAST, Germany)
J.L. Bento Coelho (CAPS - Instituto Superior Técnico, Portugal)
N. Blanes Guardia (ETCLUSI, Spain)
A. Bloomfield (Consultant, United Kingdom)
L. Cavadini (EUROCONTROL, France)
P. de Vos (DHV bv, The Netherlands)
G. Dutilleux (CETE de l'est, France)
I. Granoien (SINTEF ICT, Norway)
J. Hinton (Birmingham City Council, United Kingdom)
H. Jonasson (SP Technical Research Institute, Sweden)
N. Jones (Extrium, United Kingdom)
R. Jones (DeltaRail, United Kingdom)
E. Le-Duc (SETRA, France)
G. Licitra (ARPAT, Italy)
A. Malige (DGAC/STAC, France)
U. Moehler (Moehler + Partner, Germany)
V. O' Malley (National Roads Authority, Ireland)
M. Paviotti (Noise consultant, Italy)
B. Plovsing (DELTA, Denmark)

S. Rasmussen (COWI Acoustics and Noise, Denmark)
L. Schade (Umweltbundesamt, Germany)
S. Shilton (Acustica Ltd., United Kingdom)
S. Turner (Bureau Veritas (for Defra), United Kingdom)
D. van Maercke (CSTB, France)
N. van Oosten (Anotec Consulting SL, Spain)
T. Werst (Eisenbahn Bundesamt, Germany)
R. Witte (DGMR, The Netherlands)

S. Kephelopoulos (JRC-IHCP)
F. Anfosso-Lédée (JRC-IHCP)
B. Gergely (DG ENV)
C. Nugent (EEA)

◆ **Workshop on "Target Quality and Input Values Requirements for Noise Mapping", 17-18 March 2009, Ispra**

W. Alberts (Ministry of Transport, The Netherlands)
I. Aspuru (Labein Tecnalia, Spain)
E. Aune (Health and Welfare Agency, Norway)
A. Bäckman (Expert Panel on Noise, Sweden)
J. L. Bento Coelho (CAPS - Instituto Superior Técnico, Portugal)
A. Bisceglie (Università Milano Bicocca, Italy)
P. E. Bite (Vibrocomp Ltd., Hungary)
N. Blanes Guardia (ETCLUSI, Spain)
J. Borst (TNO, The Netherlands)
Y. Bosworth (Dept. for Environment, Food and Rural Affairs, United Kingdom)
G. Bruno (Regione Lombardia, Italy)
M. Burdett (EXTRIUM, United Kingdom)
F. Chonianaki (Noise consultant, Greece)
J. L. Cueto (University of Cadiz, Spain)
P. de Vos (DHV bv, The Netherlands)
M. Dittrich (TNO, The Netherlands)
I. Dombi ((Vibrocomp Ltd, Hungary)
G. Dutilleux (CETE de l'est, LRPC de Strasbourg, France)
H. Evans (Welsh Assembly Government, United Kingdom)
J. Fons Esteve (ETC LUSI, Spain)
M. Galabova Kostova (Ministry of Environment and Water, Bulgaria)
T. Gjestland (SINTEF ICT, Norway)
A. Globevnik (A.Projekt d.o.o., Slovenja)
I. Granoien (SINTEF ICT, Norway)
R. Hernandez (University of Cadiz, Spain)
J. Hinton (Birmingham City Council, United Kingdom)
J. Hlavacek (Railway Research Institute, Czech Republic)
K. Ingold (Federal Office for Environment FOEN, Switzerland)
A.-C. Ionescu (INCDT COMOTI, Romania)
S.-E. Ionescu (INCDT COMOTI, Romania)
N. Jones (Extrium, United Kingdom)
R. Jones (DeltaRail, United Kingdom)
P. Junek (Ministry of Health, Czech Republic)
R. Kucharski (Institute of Environmental Protection, Poland)

L. Kuhelj (Environment Agency, Slovenia)
 E. Le Duc (SETRA Ministry, France)
 G. Licitra (ARPAT, Italy)
 L. Liikonen (Uusima Regional Environmental Centre, Finland)
 J. Lindmaier (Federal Environmental Agency, Germany)
 A. Määttä (Sito Oy, Finland)
 D. Manvell (Brüel & Kjaer, Denmark)
 B. Mc Kell (Faber Maunsell, United Kingdom)
 J. Michalik (Ministry of Health, Czech Republic)
 L. Mihalcik (RUVZ – Regional Health Authority, Slovak Republic)
 K. Nolan (Environmental Protection Agency, Ireland)
 V. O' Malley (National Roads Authority, Ireland)
 S.-L. Paikkala (Ministry of the Environment, Finland)
 D. Palmer (Faber Maunsell, United Kingdom)
 E. Poikolainen (Finnish Rail Administration, Finland)
 W. Probst (DataKustik GmbH, Germany)
 T. Przybilla (Landesamt für Natur, Umwelt und Verbraucherschutz, Germany)
 E. Quaia (Università degli Studi di Milano Bicocca, Italy)
 S. Radaelli (Università degli Studi di Milano Bicocca, Italy)
 S. Routama (Finavia, Finland)
 E. Salomons (TNO, The Netherlands)
 L. Schade (Umweltbundesamt, Germany)
 S. Shilton (Acustica Ltd., United Kingdom)
 R. Silvaggio (APAT, Italy)
 A. Stenman (Tyrens Akustik AB, Sweden)
 A. Stimac (DARH 2 Acoustics & Civil Eng. Ltd., Croatia)
 S. Turner (Bureau Veritas (for Defra), United Kingdom)
 V. Uscila (State Environmental Health Centre, Lithuania)
 X. Valero Gonzalez (Ramon Llull University, Spain)
 A.-J. van Beek (Netherlands Environmental Assessment Agency, The Netherlands)
 M. van Den Berg (Ministry VROM, The Netherlands)
 H. van Leeuwen (DGMR, The Netherlands)
 D. van Maercke (CSTB, France)
 N. van Oosten (Anotec Consulting SL, Spain)
 F. van Ryn (Netherlands Environmental Assessment Agency, The Netherlands)
 A. Vasileiadis (Freelancer, Acoustics & Noise Consultant, Greece)
 M. Weber (DCMR Environmental Protection Agency, The Netherlands)
 T. Werst (Eisenbahn Bundesamt, Germany)
 E. Wetzel (Wölfel Messsysteme, Germany)
 F.-C. Zacharias (TLUG, Germany)

S. Kephelopoulos (JRC-IHCP)
 M. Paviotti (JRC-IHCP)
 G. Balazs (DG ENV)
 C. Nugent (EEA)
 W. Schneider (DG ENTR)
 S. Arrowsmith (EASA)
 G. Gardiol (European Railway Agency)

CHAPTER I. INTRODUCTION

I.1. Background and objectives of this report

The European Directive on the Assessment and Management of Environmental Noise (2002/49/EC) (END) of the European Parliament and of the Council requires that the EU Member States produce strategic noise maps for main roads and railways, main airports and agglomerations. Based on these strategic noise maps, noise action plans should be prepared and published in order to inform the general public about the levels of noise they are exposed to and the actions which are undertaken to reduce this exposure at noise levels not harmful for the public health.

One of the objectives of the END is to establish a common approach to assess the exposure to environmental noise throughout the European Union. For this purpose, a set of common noise indicators is defined in the Directive, viz. the day-evening-night level L_{den} and the night level L_{night} and strategic noise maps are started to be produced by the EU Member States in accordance with Article 7 of the END. The main objective of strategic noise mapping is to assess the exposure of people living in agglomerations or in the vicinity of main roads, railways, industrial sites and airports via these common indicators.

Article 6.2 of the END empowers the Commission to establish common assessment methods for the determination of the noise indicators L_{den} and L_{night} . Until these methods are adopted, Member States may use assessment methods adapted in accordance with Annex II of the END and based upon the methods laid down in their own legislation provided that these latter methods give equivalent results to the results obtained with the methods set out in paragraph 2.2 of Annex II.

The Commission assessed the degree of comparability of the results generated by the different methods in 2006 and 2007 during the first round of strategic noise mapping and identified that the assessment methods laid down in the national transposing measures differ significantly from the interim methods in several cases (NOISE-I administrative arrangement between DG ENV and DG JRC). Moreover, assessments have shown that it remains difficult to present comparable figures on the number of people being exposed to excessive noise levels across the EU Member States.

In accordance with Art. 6.2 of the Environmental Noise Directive 2002/49/EC (END), the European Commission then decided to develop **Common NOise aSSessment methOdS (CNOSSOS-EU)** for *road traffic*, *railway traffic*, *aircraft* and *industrial* noise to be used after adoption by the Member States for strategic noise mapping as required by the END.

This report defines a common noise assessment methodological framework (CNOSSOS-EU) which is compatible with the aforementioned common noise indicators and forms the technical basis for amending Annex II of Directive 2002/49/EC relating to the assessment and management of environmental noise in Europe via a Commission Implementing Decision in early 2012. The objective is to have it operational in and implemented by the EU Member States starting from the 3rd round of strategic noise mapping in 2017.

At a later stage, CNOSSOS-EU will be extended to allow its application on a voluntary basis for other specific type of local scale and more specific assessments with requirements of precision and accuracy higher than those associated to and can be afforded by strategic noise mapping.

The CNOSSOS-EU methodological framework described in this report is the fruit of an intensive and in-depth consultation, which involved a wide array of noise experts in two consecutive phases. The first and informal phase (March 2009 to May 2010) prepared the ground for the formal consultation and the technical development that were undertaken with the Member States during the second phase of the project (November 2010 to December 2011). The outcome of all events pertaining to both phases (i.e., Workshops, ad hoc technical meetings and meetings of the CNOSSOS-EU Technical Committee and its associated Working Groups can be retrieved via the CIRCA web site of DG ENV (<http://circa.europa.eu/Public/irc/env/noisedir/library>)

This report describes the outcome of eight out of thirteen Working Groups (WGs) of the CNOSSOS-EU Technical Committee² established under the Noise Regulatory Committee on 13 December 2010 and co-ordinated by the European Commission's Joint Research Centre – Institute for Health and Consumer Protection, namely:

WG 1 on “Quality Framework”; WG 2 on “Road traffic noise source emission”; WG 3 on “Railway traffic noise source emission”; WG 4 on “Aircraft noise prediction”; WG 5 “Sound propagation and industrial noise source emission”; WG 6 “Guidance for the competent use of CNOSSOS-EU” (conceptualisation of the guidance); WG 9 on “Revised Electronic Noise Data Reporting Mechanism” (ENDRM)³ (conceptualisation of the revised ENDRM) and WG 10 on “Assigning noise levels and population to buildings”.

The outcome of the work performed by the aforementioned WGs constitute the core part of the CNOSSOS-EU methodological framework which will feed from a technical standpoint the legal text of the Implementing Act related to the amendment of Annex II of the Directive 2002/49/EC.

Four other WGs (plus the completed versions of the CNOSSOS-EU guidance and the EEA's revised ENDRM) pertain to the operational and implementation phase of CNOSSOS-EU (2012-2015) in the EU Member States and will be activated once the amendment of Annex II of the Directive will come into force. These four WGs are the following:

WG 7 on “CNOSSOS-EU Database of input data”; WG 8 on “CNOSSOS-EU reference software”; WG 12 on “Pilot studies for CNOSSOS-EU validation” and WG 13 on “Help desk and Training of EU MS”.

One additional working group (WG 11) was established to liaise with the on-going activities on “Burden of disease estimation” which are co-ordinated by WHO-European Centre for Environment and Health. This will greatly help to assess the burden of disease due to environmental noise by benefiting from the noise exposure data gathered in the context of the planned rounds of strategic noise mapping in Europe.

This report describes the methodological aspects of CNOSSOS-EU, however, does not include the input values and databases to be used for applying CNOSSOS-EU in practice throughout Europe. It should be underlined that, CNOSSOS-EU does not aim at covering the full range of existing national and regional peculiarities. However, in the Guidelines for the competent use of CNOSSOS-EU to be developed by WG 6 during the operational phase of

² Terms of Reference of the CNOSSOS-EU Working Groups can be found at DG ENV's CIRCA web site on environmental noise

³ The chapter on the “Revised Electronic Noise Data Reporting Mechanism” is under preparation by WG 9 co-ordinated by the European Environment Agency (EEA) and will be incorporated into the final version of the present report (planned for November/December 2011)

CNOSSOS-EU ways to introduce national or regional data will be described, for example particular road surface types or vehicle types used in some Member States.

The noise assessment to be performed via CNOSSOS-EU will rely largely on the availability and quality of input data. The objective is to apply CNOSSOS-EU in a consistent way that optimises among the input data collection requirements, the acceptable cost of producing noise maps over the various rounds of strategic noise mapping in EU and the associated computational time incurred and the accuracy of the assessment desired.

I.2. Definitions and symbols

I.2.1. General concepts

Line source / line source segment

A line source is an approximate trajectory of a moving equivalent point source or a series of point sources along the line source in case of fixed sources. For practical reasons, a line source can be approximated by a set of straight-line segments (polyline), however, ideally, it could be represented by a curve in space.

A line source is characterised by a continuous distribution of point sources. The strength of a line source is expressed as directional sound power per meter per frequency band and towards a specific direction in space. All relevant parameters that define source strength will be incorporated, including horizontal and vertical directivity if applicable. In practice, the continuous distribution of point sources will be replaced by a discrete distribution, i.e. equivalent point sources placed at representative positions along the source line. See also “Point source” definition in the following.

The segmentation process consists of:

- 1) the splitting of source lines into smaller source line segments and
- 2) the replacement of the segments by equivalent point sources

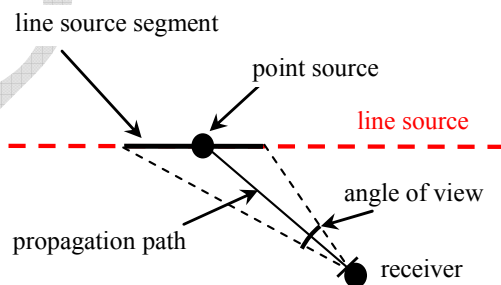


Figure I-1: Line source, line source segment, propagation path and angle of view

Propagation sector / angle of view

An angular sector drawn from the receiver to both ends of the line source segment. The angle between the lines from the receiver to both ends of the line source segment is called the angle of view of the propagation sector (figure I-1).

Propagation sectors may include reflections from nearly vertical obstacles by using the image of either the source or the receiver through the reflecting plane in place of the true position.

Homogeneous propagation sector

A propagation sector is considered to be homogeneous if:

- 1) the directional sound power of the source is almost constant over the source line segment, and
- 2) the excess propagation attenuation within the sector is slowly varying with the position along the source line

Within a homogeneous propagation sector, the line source segment can be replaced with a single equivalent point source and the excess attenuation can be calculated in a single representative propagation plane through this point source.

Point source

Line source segments will be represented by a number of mutually incoherent point sources at different height from which the acoustical energy radiates. Point source strength is expressed by the directional source sound power level $L_{w,0,dir}$ per frequency band and towards a specific direction in space. All relevant parameters that define source strength will be incorporated, including horizontal and vertical directivity if applicable. See also “Sound power” definition in the following.

Point sources are situated at the intersections of each propagation path with each line source.

Vehicle model

The acoustical description of a single, moving vehicle at specific speed and acceleration. A single vehicle might be composed of one or several mutually incoherent sub-sources at different positions, the strength of which is defined in terms of their sound power level and directivity.

Traffic model

The acoustical description of a traffic flow, based on the sound power levels of single moving equivalent vehicles. In the traffic model, the specific sound power output is combined with statistical data, yielding an equivalent noise emission for each sub-source in order to produce the source strength of the relevant source line segments.

N.B.: As a single vehicle can be represented by one or a set of point sources at different heights, the resulting traffic model will consist of one or a set of superimposed source lines that share a single footprint on the ground.

Receiver

A single point at which the incident time averaged sound intensity level will be calculated. A distinction should be made between free-field receivers that have propagation paths in all

directions (360°) and receivers that represent the incoming acoustical energy on a façade. The latter will have a total viewing angle of 180° and a bisector perpendicular to the façade.

Propagation plane

A propagation plane is a vertical plane passing through the source and receiver positions. The intersection of the propagation plane with the geometrical (surface) model is represented by a series of connected line elements representing the terrain, the buildings and the barriers in a vertical cross-section. It is assumed that the effects of ground reflections, diffraction over obstacles and meteorological refraction can be predicted with sufficient accuracy from the geometrical and the acoustical properties in the cross-section.

An illustration of this approximation for the situation with barriers at an arbitrary angle to the source-receiver line is shown in figure I.2.

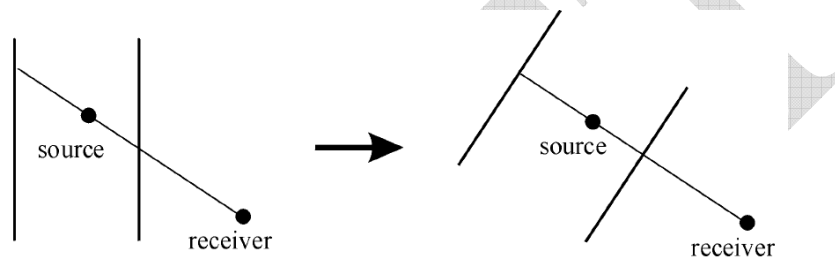


Figure I.2: Illustration of the 2-D approximation: the situation with barriers at an arbitrary angle to the source-receiver line (*left*) is replaced by a situation with barriers perpendicular to the source-receiver line (*right*).

Propagation path / geometrical cross-section

A propagation path is defined as the projection of a propagation plane on the horizontal plane. Propagation paths are essentially a 2-dimensional projected view of the site and the third dimension is added only to calculate the excess attenuation along these paths.

Propagation paths can be classified according to their geometrical characteristics:

- **Direct propagation paths** are straight lines linking the source directly to the receiver. This does not necessarily imply that the source is in direct view of the receiver: as the propagation path is constructed in 2-D it may pass over obstacles that block the line of sight.
- **Reflected propagation paths** are generated by vertical obstacles. It is assumed that such paths obey the laws of specular reflection in the horizontal plane. Note that reflections from the ground are taken into account by the Point-to-Point model and should not be considered as independent propagation paths.
- **Laterally diffracted propagation paths** are generated by vertical edges of obstacles. For extended (road, railway and aircraft) sources such paths usually have negligible contributions on the total sound levels and can therefore be omitted. For relatively small-sized sources (i.e. sources elements with size smaller than the

propagation distance) like in the case of industrial areas or tunnel opening, the model may be extended to include such paths.

- Propagation paths containing any **combination** of reflections and diffractions from vertical obstacles.

Ray path

Each propagation path consists of a set of coherent ray paths. The shortest of these ray paths is called the “main ray path”; a ray path can be either direct (source in view of the receiver), reflected, diffracted or include any combination of these.

The main difference between ray paths and propagation paths is the way the different contributions are added: over propagation paths, incoherent summations are performed (addition of sound energies $|p|^2$) whereas over ray paths, coherent summations are performed (addition of sound pressures p).

The CNOSSOS-EU method uses coherent summation only for ray paths lying in a single vertical propagation plane (i.e. to estimate the effects of reflection on the ground). These effects are built into the point-to-point module described in chapter V. Different propagation paths, even when originating from a single point source, are always considered as incoherent.

CNOSSOS-EU is basically a 2.5D method in the sense that:

- It operates on a 2.5D geometrical model, consisting in a connected set of surfaces that are either almost horizontal or almost vertical. Almost horizontal surfaces include terrain, roofs of buildings, road surfaces, etc. Almost vertical surfaces include barriers and façades of buildings.
- Propagation paths and sectors are constructed in 2D, in the horizontal plane and include direct, reflected and diffracted paths. Direct paths include those diffracted over obstacles. Reflected paths come from almost vertical surfaces. Diffracted paths come from vertical edges shared by vertical planes.
- Once a propagation path is found, it is converted into a propagation plane, derived from the intersection of a (set of) vertical plane(s) through the propagation path with the underlying 2.5D geometrical model. The outcome is a vertical cross section that is used as the input to the point-to-point module.

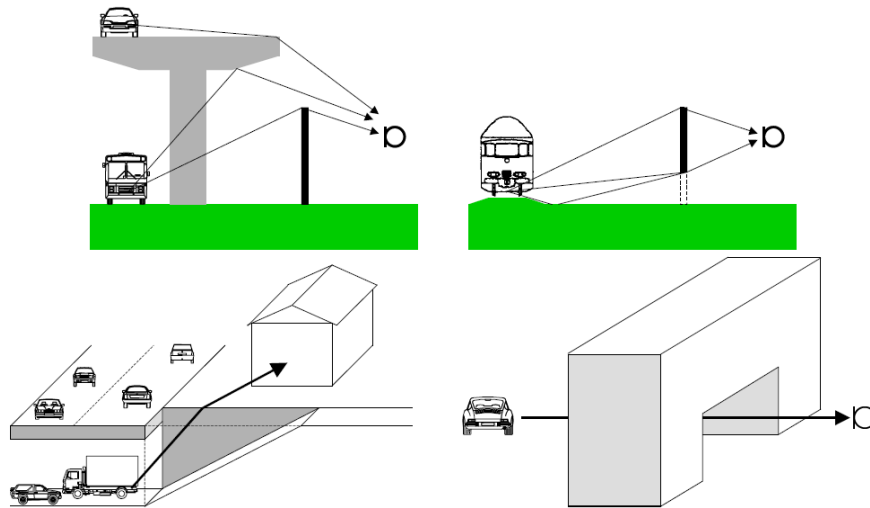


Figure I.3: Examples of ray paths in complex geometries

The two upper cases in Fig.I.3 have additional ray paths compared with “regular” geometries. Advanced path detection methods are required in such cases. In the two lower cases, it is more efficient to use algorithms for propagation through tunnels and for radiation from openings rather than generating numerous (higher order) reflection paths.

N.B.: the CNOSSOS-EU methods are NOT intended to be used in combination with true 3D path finders.

Sound power

In the CNOSSOS-EU model, the acoustical emission of all sources is defined as directional sound power emitted per frequency band. Real sources are commonly close to reflecting surfaces that are included in the source definition like e.g.: as defined in the ISO 9614. The sound power of the source is defined as the total equivalent sound power that includes eventual effect of reflections by the surface immediately next to the real source and in a specific direction in space. For road and railway these nearby surfaces are the surfaces (e.g.: asphalt, ballast) under the source; for industrial noise it can be the ground under a source and/or the close by vertical surface, if any, opposite to the direction source-receiver. This sound power is commonly defined as in "semi-free field". Any surface that has been included and accounted to determine the directional source sound power shall not be used in the propagation calculation. **Instructions for converting between different approaches to sound power determination will be given in the Guidance for the Competent Use of CNOSSOS-EU.**

Meteorological effects

Wind speed and air temperature gradients cause refraction of the ray path. For accurate calculation of propagation effects such as barrier attenuation and ground reflections, the definition of the ray path must comply with defined meteorological conditions that are representative for the site. Therefore, a distinction will be made between e.g. downwind propagation (downward refraction), propagation under neutral conditions (straight propagation paths) and eventually, upwind propagation (upward refraction). Positive temperature gradients (“inversion”) have similar effects (if not more pronounced) as downwind conditions.

Meteorological data

Since the definition of the ray path depends on meteorological conditions, statistical data on temperature gradients, wind speed and wind directions in relation to source and receiver must be collected. Furthermore, meteorological conditions such as temperature, snow covering and precipitation influence the sound power output of the sources. Such input data may prove too difficult to obtain, in which case associated parameters might be used, e.g. cloud covering instead of vertical temperature gradients.

In practice, since meteorological conditions, especially wind speed and direction, can vary rapidly over time, a statistical classification of these meteorological conditions is necessary for modelling purposes. These meteorological classes must be defined such that variations within these classes have an acceptably small effect on the predicted noise levels. However, these meteorological classes must be realistic with regard to data collection and handling.

From each meteorological class, combined with possible variations in source strength, short term noise levels will be calculated. The yearly average noise indicators L_{den} and L_{night} can then be determined by the combination of these short-term noise levels with their occurrence.

The following are the definitions of the terms used concerning atmospheric conditions:

- homogeneous atmospheric conditions (or “homogeneous conditions”)

atmospheric conditions for which the effective speed of sound waves may be considered as constant in all directions and at any point of the propagation space. In these conditions, sound rays are straight segments.

- atmospheric downward-refraction conditions (“favourable conditions”)

atmospheric conditions for which the effective speed of sound waves increases with altitude in the direction of propagation. These conditions generally result in sound levels at the receiver higher than those observed in homogeneous atmospheric conditions for an identical sound source. The sound rays are curved towards the ground

- atmospheric upward-refraction conditions (or “unfavourable conditions”)

atmospheric conditions for which the propagation effective speed of sound waves decreases with altitude in the direction of propagation. These conditions generally result in sound levels at the receiver lower than those observed in homogeneous atmospheric conditions for an identical sound source. The sound rays are curved towards the sky. This document does not propose calculation formulae for unfavourable conditions.

- long-term occurrence of downward-refraction conditions (or occurrence of favourable conditions), p

probability of occurrence of favourable atmospheric conditions over a long period in a given direction and for the reference interval considered. This value is dimensionless and is between 0 and 1

I.2.2. Frequency range and bands definitions

The CNOSSOS-EU method is valid for the frequency range from 100 Hz to 5 kHz. It provides frequency band results at the corresponding frequencies interval.

Based on these 1/3-octave band results, the A-weighted sound pressure level $L_{eq,T}$ is computed by summation over all frequencies:

$$L_{eq,T} = 10 \times \lg \sum_{i=1}^{27} 10^{(L_{eq,T,i} + A_{f,i})/10} \quad (I-1)$$

where $A_{f,i}$ denotes the A-weighting correction according to IEC 61672-1. As a minimum implementation, the 1/1 octave bands are to be used.

I.2.3. Indicators

Noise indicators

The long-term average noise indicator specified in the European Directive 2002/49/EC, is the day-evening-night indicator, L_{DEN} defined by:

$$L_{DEN} = 10 \lg \left[\frac{12}{24} 10^{L_{day}/10} + \frac{4}{24} 10^{(L_{evening} + 5)/10} + \frac{8}{24} 10^{(L_{night} + 10)/10} \right] \quad (I-2)$$

where

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

The day is 12 hours, the evening four hours and the night eight hours, and a year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances. Day, evening and night periods may be defined slightly different at National level.

The parameters used in the various formulations are usually defined locally in the respective sections. A few general parameters are common to the formulations, and they are summarised in the tables below.

Noise parameters:

L_p	Instantaneous sound pressure level	[dB] (re. $2 \cdot 10^{-5}$ Pa)
$L_{Aeq,LT}$	Global long-term sound level LAeq due to all sources and image sources at point R	[dB] (re. $2 \cdot 10^{-5}$ Pa)
L_W	Sound power level of a point source (moving or steady)	[dB] (re. 10^{-12} W)
$L_{W,i,dir}$	Directional “in situ” sound power level for the i-th frequency band	[dB] (re. 10^{-12} W)
$L_{W'}$	Average sound power level per meter of equivalent line of point sources	[dB] (re. 10^{-12} W)

Other physical parameters:

p	r.m.s. of the instantaneous sound pressure	[Pa]
p_0	Reference sound pressure = $2 \cdot 10^{-5}$ Pa	[Pa]
W_0	Reference sound power = 10^{-12} W	[Watt]

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CHAPTER II. QUALITY FRAMEWORK⁷

II.1. Objective of CNOSSOS-EU

The main objective of the CNOSSOS-EU methodological framework is the following:

The process should develop a consistent method of assessment capable of providing comparable results from the strategic noise mapping carried out by Member States to fulfil their obligations under the END.

II.2. Requirements

1. The method should be designed to produce plausible noise maps showing plausible results.
2. The precise sources/scope to be included in the strategic mapping should be defined:
 - a. For road transport, such as, exactly which roads should be included in the road noise mapping of an agglomeration.
 - b. For rail transport, such as, exactly which railways, trams and light rail systems should be included in the railway noise mapping of an agglomeration.
 - c. For industry, such as, exactly the industry types to be included in the agglomerations.
 - d. For air transport, such as, the precise airports that should be mapped, in particular in relation to non-major airports affecting agglomerations. In so doing, the burden placed on the non-major airport should be balanced against its aircraft noise impact. A precise definition is required for the source information to be used with airport noise mapping, in particular in connection with flight profiles, dispersion etc.
 - e. For agglomerations, exactly how an agglomeration should be defined for the purposes of strategic noise mapping should be defined.
3. It is recognised that it is essential for some input parameters to be included in the mapping, but that others are only significant in specific local situations. To provide consistency, the source Working Groups should identify the essential input parameters. For the purposes of this method, a parameter is considered essential if the range of values the parameter can take across Europe yields variations in the yearly averaged L_{den} or L_{night} at a particular receptor position of more than ± 2.0 dB(A) 95% C.I. (all other parameters remaining unchanged). Parameters not considered essential should either be aggregated with the relevant essential parameter, and/or have a default input value defined.
4. In the application of the method, the input data for the essential parameters should reflect the actual usage and there should be no reliance on default input values or assumptions of the type found in the Guidelines for Competent Application of CNOSSOS-EU.
5. Taking into account the requirement of (3) above, the accuracy required from the essential input data should be defined.
6. The conditions for including information in the model about obstacles on the propagation path should be defined.

⁷ The text of this chapter has been redrafted in mid-September 2011 and should be still discussed with and revised by the CNOSSOS-EU WG 1

7. A precise definition should be given about how exposure assessments should be carried out, designed to meet the requirement of (1) above. This applies equally to dwelling exposure, area exposure and population exposure.
8. In all their decision making the source Working Groups should take account of the cost to MSs of obtaining the required actual input data and of undertaking the periodic strategic noise mapping. This applies especially to the definition of sources to be included of (2) above, to the definition of the essential parameters of (3) above and to the specification of requirements on input data quality of (5) above.

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CHAPTER III. ROAD TRAFFIC NOISE SOURCE EMISSION⁸

III.1 Source description

III.1.1. Classification of vehicles

Road traffic noise results from the addition of the noise emission of each individual vehicle forming the traffic flow. These vehicles shall be grouped into four categories with regard to their characteristics of noise emission:

Category 1: *Light motor vehicles*

Category 2: *Medium heavy vehicles*

Category 3: *Heavy vehicles*

Category 4: *Powered two wheelers*

In the case of powered two-wheelers, two separate subclasses are defined for mopeds and more powerful motorcycles, since they operate in very different driving modes and their occurrence usually differs strongly.

A fifth category is foreseen as an open class for new vehicles to be developed in the future and sufficiently different in their noise emission to require an additional category to be defined. This category could cover for example electric or hybrid vehicles or any futuristic vehicle. No data are available at this stage for vehicles in category 5.

⁸ The content of this chapter is only provisional and will be updated by CNOSSOS-EU WG 2 after elaborated and agreed on the three following main and still pending issues for which no consensus has been achieved so far: 1- source position (both above the road and across the road); 2- regional correction (definition and application or no application); 3- stage at which the frequency distribution is to be applied

The details of the different vehicle classes are given in Table III.1.

Table III.1 - Vehicle classes

Category	name	description	vehicle category in EC Whole Vehicle Type Approval ⁽¹⁾
1	Light motor vehicles	Passenger cars, delivery vans ≤ 3.5 tons, SUV's ⁽²⁾ , MPV's ⁽³⁾ including trailers and caravans	M1 and N1
2	Medium heavy vehicles	Medium heavy vehicles, delivery vans > 3.5 tons, buses, touring cars, etc. with two axles and twin tyre mounting on rear axle	M2, M3 and N2, N3
3	Heavy vehicles	Heavy duty vehicles, touring cars, buses, with three or more axles	M2 and N2 with trailer, M3 and N3
4	Powered two-wheelers	4a mopeds, tricycles or quads ≤ 50 cc	L1, L2, L6
		4b motorcycles, tricycles or quads > 50 cc	L3, L4, L5, L7
5	Open category	To be defined according to the needs in the future	N/A

⁽¹⁾ Directive 2007/46/EC of the European Parliament and of the Council of 5 September 2007 (OJ L 263/1 9/10/2007) establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles.

⁽²⁾ Sport Utility Vehicles

⁽³⁾ Multi-Purpose Vehicles

Note: As explained in the Guidelines for a Competent use of CNOSSOS-EU, for the purpose of strategic noise mapping, at least the first three categories should be considered: light motor vehicles (category 1), medium heavy vehicles (category 2) and heavy vehicles (category 3).

III.1.2. Number and position of equivalent sound sources

For the calculation of noise propagation and for the determination of sound power emission, it is necessary to describe the source with one or several point sources. In this method, each vehicle (Cat. 1, 2, 3 and 4) is represented by one single point source. As depicted in figure III.1, the heights of the point sources are located as follows:

- Light motor vehicles (Cat. 1): the equivalent point source is located at x m above the road.
- Heavy motor vehicles (Cat. 2 and 3): the equivalent point source is located at x m above the road.
- Two-wheelers (Cat. 4): the equivalent point source is located at x m above the road.

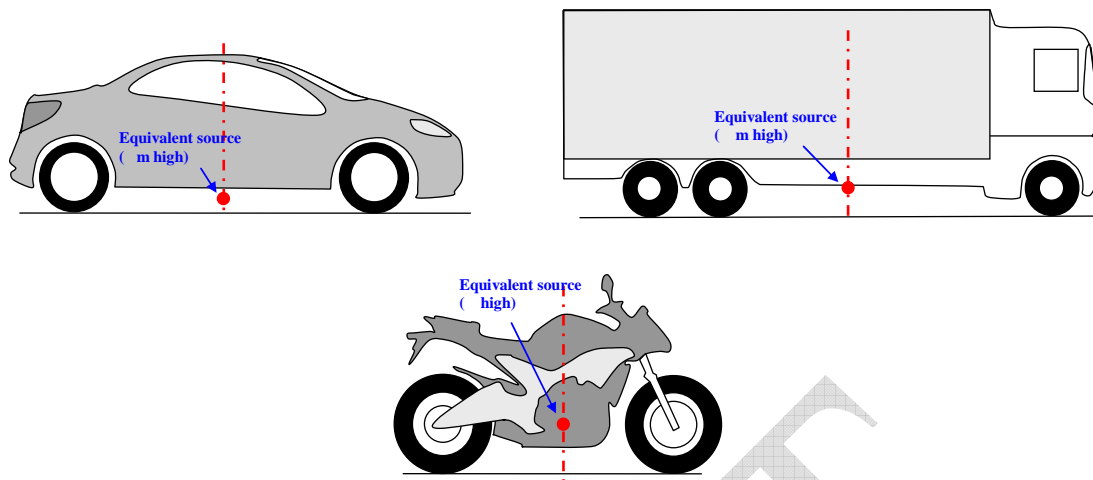


Figure III.1: Location of equivalent point source on light vehicles (cat.1), heavy vehicles (cat.2 and 3) and two-wheelers (cat.4).

The method for deriving sound power levels from roadside sound pressure measurements will be described in the Guidance for the competent use of CNOSSOS-EU.

Horizontal extent of the source in the driving direction is implicitly taken into account since the traffic stream, or part of it, is represented by a line source. This line source is located in the vertical plane of the centre of the driveway.

III.2 Sound power emission

III.2.1. General considerations

The sound power of the source is defined as the total sound power in semi-free field, without any disturbing objects in its surrounding except the reflection on the road surface. This description is consistent with the propagation calculation scheme detailed in Chapter VI.

Individual vehicle

The model for road traffic noise describes the noise emission of an "average" European road vehicle in terms of sound power level. It defines the instantaneous noise production of a vehicle defined by the two main parameters - category, speed - and corrected for several environmental or specific effects. The calculations are performed with separate speeds for Cat. 1, Cat. 2 and 3 and for Cat. 4. Usually, these speeds are dependent on the maximum allowed speed of the road for each category.

For each road vehicle, the emission model consists of a set of mathematical equations representing the two main noise sources:

1. Rolling noise due to the tyre/road interaction;
2. Propulsion noise produced by the driveline (engine, exhaust, etc.) of the vehicle;

Aerodynamic noise is incorporated in the rolling noise sources, since the chosen method of determination of the sound power level determined from coast-by events makes it impossible to distinguish between the two. The effect of aerodynamic noise on the source height can be neglected since detailed measurements have demonstrated that the sources for flow noise are also located in the wheel arches and under the car. Aerodynamic noise is considered to be of influence only at high vehicle speeds.

The general form of the mathematical expression for the sound power level emitted by one of the sources (rolling or propulsion) as a function of the vehicle speed v ($20 \text{ km/h} \leq v \leq 130 \text{ km/h}$) is:

$$L_{W,i,m}(v) = A_{i,m} + B_{i,m} \cdot f(v) \quad (III-1)$$

with $f(v)$ being either a logarithmic function of the vehicle speed v in the case of rolling and aerodynamic noise, and a linear function of v in the case of propulsion noise. The sound power level $L_{W,i,m}$ is calculated in octave bands from 63 Hz to 8 kHz, where the subscript i indicates the spectral frequency band. The index m represents the vehicle category as defined in section III.1.1.

For light and heavy motor vehicles (Cat. 1, 2 and 3), the sound power corresponds to the energetic summation of the rolling and the propulsion noise. Thus, the sound power level of the equivalent sound source ($L_{W,i,m}$) for $m=1,2$ or 3 is defined by:

$$L_{W,i,m}(v) = 10 \times \lg \left(10^{L_{WR,i,m}(v)/10} + 10^{L_{WP,i,m}(v)/10} \right) + \Delta L_{W,road,i,m}(v) \quad (III-2)$$

where $L_{WR,i,m}$ is the sound power level for rolling noise and $L_{WP,i,m}$ is the sound power level for the propulsion noise. Their calculation is described in sections III.2.3 and III.2.4 respectively.

$\Delta L_{W,road,i,m}$ accounts for the effect of the type of road surface. The calculation is detailed in section II.2.5.

For two-wheelers (Cat. 4), only propulsion noise is considered for the equivalent sound source:

$$L_{W,i,m=4}(v) = L_{WP,i,m=4}(v) \quad (III-3)$$

N.B.: In the rest of this chapter, all the sound power levels and correction coefficients are expressed for each category m ($m = 1$ to 4) and for each octave band i ($i = 1$ to 8) in the range [63 Hz – 8 kHz]. By default, the subscripts “ i ” and “ m ” are implicit in all the indicators, but they will be omitted to improve the readability of the text.

Traffic flow

The noise emission of a traffic flow is represented by a line source characterised by its sound power per unit length. This corresponds to the sum of the sound emission of the individual vehicles in the traffic flow, taking into account the time spent by the vehicles in the considered road section. The implementation of the individual vehicle in the flow requires the application of a traffic flow model ([4], [5]).

If a steady flow of N vehicles during the period T (in seconds) is assumed, with an average speed V (in m/s), the noise emission of the vehicle flow in terms of an equivalent line source strength (average sound power level per unit length) $L_{W',eq,line}$ is defined by:

$$L_{W',eq,line} = L_{W,0} + 10 \times \lg\left(\frac{N}{T \times V}\right) \quad (III-4)$$

where $L_{W,0}$ is the instantaneous sound power level of the equivalent sound source of a single vehicle according to equation (III-2). In equation (III-4), the unit length is meter, $L_{W',eq,line}$ is expressed in dB/m (re. 10^{-12} W).

In the common case of vehicle speed v defined in km/h and vehicle flow Q in vehicles/hour, the sound power per meter is given by:

$$L_{W',eq,line} = L_{W,0} + 10 \times \lg\left(\frac{Q}{1000 \times v}\right) \quad (III-5)$$

For the purpose of strategic noise mapping, a minimum of one line source per driving direction should be used in the case of large roads, i.e. roads with four or more lanes, especially when there are separate carriageways and a central reservation. The same rule applies to parts of roads with a significant gradient ($> 2\%$) and with parts of roads where acceleration effects are considered. For all other simpler configurations, a minimum of one source for the road as a whole is accepted. This source should be placed in the middle of the road platform. More advanced distribution may be defined by EU Member States if felt necessary. Examples are provided in the Guidelines for a competent use of CNOSSOS-EU.

III.2.2. Reference conditions

The source equations and coefficients are derived to be valid under reference conditions for meteorology and traffic situation. These reference conditions are:

- constant vehicle speed,
- a flat road, i.e. with a slope s (in %), such as $|s| \leq 2\%$
- an air temperature $\tau_{ref} = 20$ °C,
- a virtual reference road surface, consisting of an average of Dense Asphalt Concrete 0/11 and Stone Mastic Asphalt 0/11 with an age between 2 and 7 years and in a representative maintenance condition. Sound reflection properties are assumed on this reference surface.
- a dry road surface,
- a vehicle fleet for which the characteristics correspond to the values found for the European average:
 - ◊ an average tyre width of 187 mm for Category 1 vehicles,
 - ◊ an average fraction of diesel engines of 19% for Category 1 vehicles,
 - ◊ an average distribution of delivery vans of 10.5% in Category 1,
 - ◊ no studded tyres,

◇ an average number of 4 axles for Category 3 vehicles,

For situations deviating from these reference conditions, correction factors are introduced, as described in the following sections.

III.2.3. Rolling noise

III.2.3.a General equation

For rolling noise, the generally accepted and widely validated logarithmic relation between rolling noise emission and rolling speed v is used. The sound power level L_{WR} is expressed by:

$$L_{WR} = A_R + B_R \times \lg\left(\frac{v}{v_{ref}}\right) + \Delta L_{studded\ tyres}(v) \quad (III-6)$$

The coefficients A_R and B_R are given in Appendix III-A in octave bands for each vehicle category, and for a reference speed $v_{ref} = 70$ km/h. They are defined in the reference conditions described in section III.2.2.

$\Delta L_{studded\ tyres}$ is a correction coefficient, to be applied to the proportion of light vehicles equipped with studded tyre. This speed-dependant correction is taken from the interim model for Nordic countries [10], and is given by:

$$\Delta L_{WR,stud} = p_s \times \begin{cases} a + b \times \lg(v/70) & \text{for } 50 \leq v \leq 90 \text{ km/h} \\ a + b \times \lg(90/70) & \text{for } v > 90 \text{ km/h} \\ a + b \times \lg(50/70) & \text{for } v < 50 \text{ km/h} \end{cases} \quad (III-7)$$

where coefficients a and b are given for each octave band in table III.A.1, and p_s is the proportion of vehicles with studded tyres.

Studded tyres for trucks are not very common, though they may exist. Therefore, no correction for studded tyres is introduced for categories 2 and 3.

As stated above, the aerodynamic noise of the vehicle is incorporated in the rolling noise equation.

The variation with speed of the overall rolling sound power for the light and heavy categories of vehicles ($m = 1, 2$ and 3) is presented in figure III.2.

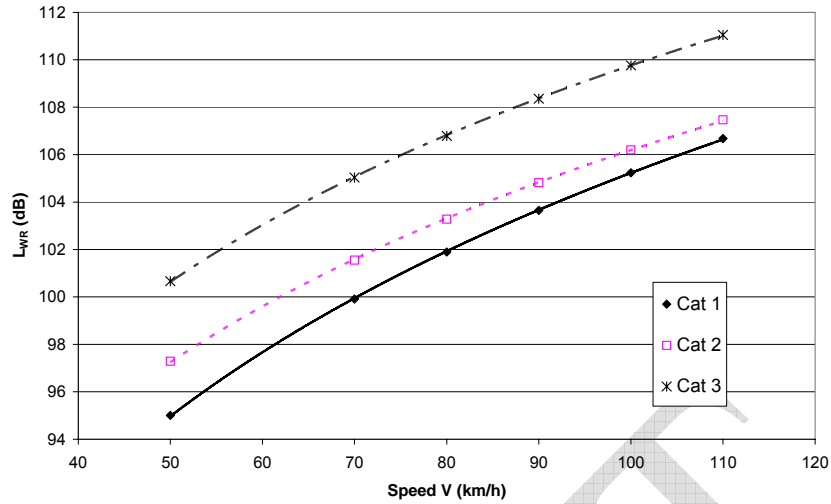


Figure III.2: Rolling sound power levels in dB for the first three categories of vehicles in reference conditions.

III.2.4. Propulsion noise

III.2.4.a. General equation for steady speed conditions

The propulsion noise emission includes all contributions from engine, exhaust, gears, air intake, etc. For propulsion noise, the emission L_{WP} is formulated as follows:

$$L_{WP} = A_P + B_P \times \frac{(v - v_{ref})}{v_{ref}} + \Delta L_{WP} \quad (III-8)$$

The coefficients A_P and B_P are given in Appendix III-A in octave bands for each vehicle category, and for a reference speed $v_{ref} = 70$ km/h. They are defined in the reference conditions described in section III.2.2, in particular for a vehicle at a steady speed on a flat road.

ΔL_{WP} corresponds to the sum of the correction coefficients to be applied on propulsion noise emission for specific driving conditions or actual regional conditions deviating from the reference conditions:

$$\Delta L_{WP} = \Delta L_{WP,acc} + \Delta L_{WP,grad} \quad (III-9)$$

$\Delta L_{WP,acc}$ and $\Delta L_{WP,grad}$ account for deviations related to the driving conditions. They are detailed in sections III.2.4.b to d;

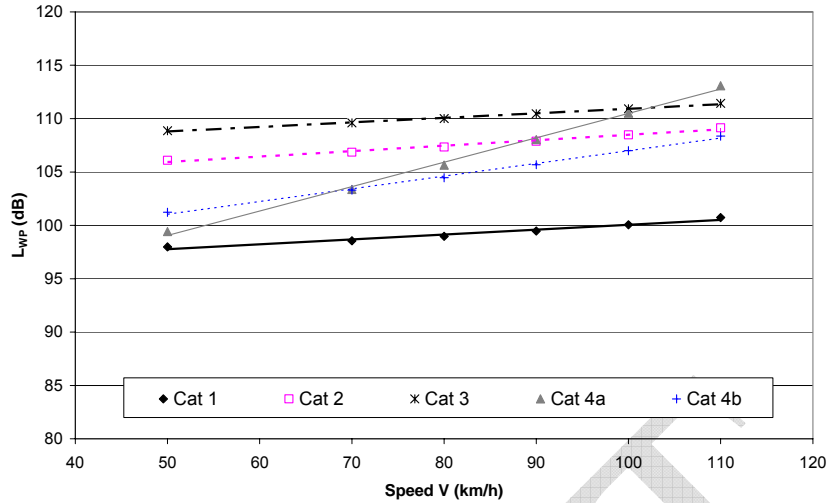


Figure III.3: Propulsion sound power levels in dB for all categories of vehicles in reference conditions.

The equation (III-9) is based on a combination of the relation between vehicle speed and engine speed and the relation between engine speed and noise. The first relation is mainly steered by the gear shifting behaviour of the driver. Several field tests have shown that although the driver operates the vehicle in a limited engine speed range, there is a clear tendency for higher engine speeds at higher vehicle speeds. The resulting linear relation between noise emission and vehicle speed is a reasonable approximation.

III.2.4.b. Acceleration and deceleration of vehicles

Acceleration and deceleration of vehicles may have a significant effect on vehicle noise emission especially when approaching or departing from road crossings. However, at the scale of a traffic flow, this effect is much more difficult to estimate than for individual vehicles, as it depends on the behaviour of individual vehicles, location, time, traffic conditions, etc. The uncertainty on the estimation of acceleration of the traffic can be higher than the effect on noise. Therefore, in most situations, the effect of acceleration and deceleration may be neglected for the purpose of the development of strategic noise maps: $\Delta L_{WP,acc} = 0$

However, EU Member States may wish to consider acceleration/deceleration effects, in order to integrate the effect of specific noise mitigation measures in strategic noise maps, such as green waves or crossing transformations. In this case, a correction can be applied before and after crossings with traffic lights as described below.

For the propulsion noise of accelerating and decelerating vehicles on a flat road, a correction $\Delta L_{WP,acc}$ is developed based on the actual (instantaneous) vehicle acceleration a in m/s^2 :

$$\Delta L_{WP,acc} = \begin{cases} C_p \times \min(a, a_{max}) & \text{for } a \geq -1 \text{ m/s}^2 \\ C_p \times (-1) & \text{for } a < -1 \text{ m/s}^2 \end{cases} \quad (III-10)$$

with

$$a_{max} = \begin{cases} 2 \text{ m/s}^2 & \text{for category 1} \\ 1 \text{ m/s}^2 & \text{for categories 2 and 3} \\ 4 \text{ m/s}^2 & \text{for category 4.} \end{cases} \quad (III-11)$$

The coefficients C_P are given in Appendix III.A.1 for each octave frequency band and for each vehicle category. The coefficients are equal for categories 1 and 4, as well as for categories 2 and 3.

III.2.4.c. Effect of road gradients

Road gradient has two effects on noise emission: first, it affects the vehicle speed and thus their rolling and propulsion noise emission; second, it affects the engine load and thus the propulsion noise emission of the vehicle. Only this second effect is considered in this section, where a steady speed is assumed. It was observed that road gradients lower than 6% have no effect on the propulsion noise of light motor vehicles (Cat. 1) [8].

Three conditions of road gradients are considered, according to the slope s :

- Flat road: for $|s| \leq 2\%$, the road gradient is neglected
- Uphill conditions: for $2\% \leq s$
- Downhill conditions: for $s \leq -2\%$

The effect of road gradient on the propulsion noise is taken into account by a correction coefficient $\Delta L_{WP,grad}$ according to the slope s [8] to be attributed to all octave bands:

For $m = 1$ or 4 $\Delta L_{WP,grad} = 0$ for all s (III-12)

For $m = 2$ or 3

$$\Delta L_{WP,grad,i} = \begin{cases} 0 & \text{for } |s| \leq 2\% \\ 2 \times (\min[100 \times s, 6] - 2) & \text{for } 2\% \leq s \\ (-\max[100 \times s, -6] - 2) & \text{for } s \leq -2\% \end{cases}$$

(II)

This correction is valid only for vehicles at steady speed $v > 20$ km/h.

N.B.: The corrections have been established for slopes $|s| \leq 6\%$. For steeper slopes $|s| > 6\%$, the correction coefficient at $|s| = 6\%$ should be used as an approximate solution. However, the uncertainty is unknown. In the case it is felt necessary to evaluate the corrections with more accuracy, specific measurements can be used as described in [8], by comparing pass-by noise levels on flat and on non flat parts of the road. The measurement protocol has to differentiate rolling and propulsion noise. A methodology for evaluating such corrections is proposed in the Guidelines for a competent use of CNOSSOS-EU.

III.2.4.d. Combined effect of road gradient and acceleration for heavy vehicles (Cat.2 and 3)

The combination of road gradient and acceleration or deceleration of heavy vehicles (Cat. 2 and 3) does not result in the sum of both effects [8]. In the case where both effects occur, the following corrections are applied:

In the case of uphill conditions ($2\% \leq s$):

$$\Delta L_{WP,acc} + \Delta L_{WP,grad} = \begin{cases} \text{Max}\{2 \times (100 \times s - 2); 5\} & \text{for acceleration conditions} \\ 0 & \text{for deceleration conditions} \end{cases} \quad (III-13)$$

In the case of downhill conditions $s \leq -2\%$:

$$\Delta L_{WP,acc} + \Delta L_{WP,grad} = \begin{cases} 5 & \text{for acceleration conditions} \\ (-100 \times s - 2) & \text{for deceleration conditions} \end{cases} \quad (III-14)$$

III.2.5. Spectral distribution⁹

The spectral distributions to be applied to the sound power emission are described in the following figures for 8 octave bands ranging from octave band centered on 63 Hz and octave band centered on 8 kHz. Tables of values can be found in Appendix III-C. The spectral distribution should be applied for each vehicle category to rolling noise and propulsion noise separately.

Figure III.4: Spectral distribution for rolling and propulsion noise of vehicles of category 1 (light vehicles).

Figure III.5: Spectral distribution for rolling and propulsion noise of vehicles of category 2 (small/medium heavy vehicles).

Figure III.6: Spectral distribution for rolling and propulsion noise of vehicles of category 3 (heavy vehicles).

Figure III.7: Spectral distribution for rolling and propulsion noise of vehicles of category 4 (two-wheelers).

⁹ The figures of section III.2.5. will be inserted after the pending issue no. 3 about the stage at which the frequency distribution is to be applied will be fixed by the CNOSSOS-EU WG 2.

III.2.6. Effect of the type of road surface

III.2.6.a. General principle

The type of road surface significantly influences the noise emission of a vehicle. On a single pass-by event on the road side, differences up to 15 dB(A) can be observed for the same vehicle at the same speed in conditions where rolling noise is predominant.

The variety of road surface types and conditions over Europe is large, leading to significantly different noise related properties across Europe. Currently there is no common procedure for the assessment of road surface noise properties, although collective suggestions for acoustical classification, checking and monitoring of road surfaces have been made [6].

The road surface characteristics affect mainly rolling noise emission, but porous sound absorbing surfaces also affect the propagation of rolling and propulsion noise. However, in practice, the effect of a road surface is usually evaluated according to international standard procedures, by comparing sound pressure levels measured on the road side that includes both source and propagation effects. Therefore, the correction factors proposed in this method for the effect of road surface include implicitly the effect of the surface on local sound reflection. Consequently, they should apply to the sum of rolling and propulsion noise and the change in surface impedance shall not be included in propagation calculations. They are based on a set of experimental data acquired on a representative selection of EU road surfaces [2].

The sound power level of the equivalent sound source defined in equation (III-2) together with emission coefficients provided in Appendix III-A are valid for the reference road surface defined in section III.2.2. This virtual reference road surface corresponds to an average of Dense Asphalt Concrete 0/11 and Stone Mastic Asphalt 0/11 with an age between 2 and 7 years and in a representative maintenance condition. For other road surfaces, it is recommended to apply a correction procedure based on a classification and labelling system as described in [6]. This procedure distinguishes between the effect on light motor vehicles (Category 1) and on that of heavy duty vehicles (Categories 2 and 3). The procedure also includes the spectral effect. Porous surfaces in particular exhibit strong spectral differences that, when neglected, lead to errors in propagation calculations over barriers, over long distances or through facades.

The effect of the road surface on the vehicle noise emission level is given by:

$$\Delta L_{W,road} = \alpha_{i,m} + \beta_m \times \lg\left(\frac{v}{v_{ref}}\right) + \Delta L_{W,temp}(\tau) \quad (III-15)$$

where : $\alpha_{i,m}$ is the spectral correction in dB at reference speed v_{ref} for category m (1, 2 or 3) and spectral band i (octave band from 63 to 8000 Hz).

β_m is the speed effect on rolling noise reduction. Although this coefficient is in principle frequency dependent, no spectral data are available in the literature and a constant value is assumed in this method.

$\Delta L_{W,temp}(\tau)$ is a correction term for average temperature τ different from the reference temperature $\tau_{ref} = 20^\circ\text{C}$. It is defined in section III.2.5.c.

Some examples of numerical values obtained on a large set of road surfaces in the Netherlands [1] for $v_{ref} = 70$ km/h are given in the informative Appendix II-E. *How to derive values from national emission databases will be described in the Guidelines for the competent use of CNOSSOS-EU.* It should be noted that road surface corrections may vary from one place to another due to different compositions or characteristics of raw materials.

III.2.6.b. Age effect on road surface noise properties

Noise characteristics of road surfaces vary with age, with a tendency to become louder over time. In particular, the acoustic lifetime of low noise surfaces is usually shorter than the one of dense surfaces, especially concrete surfaces. Therefore, the road surface correction should include ageing effect and level of maintenance effect. For this purpose, average values regarding ageing are to be estimated by averaging noise reductions over the whole life cycle. Acoustic monitoring can be performed on a regular basis by using procedures such as described in [6] to follow experimentally the evolution of the road surface correction.

III.2.6.c. Air temperature effect on road noise correction

It is generally accepted that the air temperature affects rolling noise emission: rolling sound power level decreases when the air temperature increases. This effect can be introduced in the road surface correction. Road surface corrections are usually evaluated at an air temperature of $\tau_{ref} = 20^\circ\text{C}$. In cases of a different yearly average air temperature τ the road surface correction should be corrected by

$$\Delta L_{W,temp}(\tau) = K \times (20 - \tau) \quad (III-16)$$

The corrective term is positive (i.e. noise increases) for temperatures lower than 20°C , and negative (i.e. noise decreases) for higher temperatures. The coefficient K depends on the road surface and the tyre characteristics and exhibits in general some frequency dependence. For strategic noise mapping purposes, a simplified noise calculation using a generic coefficient $K = 0.08$ dB/ $^\circ\text{C}$ for light vehicles (Cat.1) and 0.04 dB/ $^\circ\text{C}$ for heavy vehicles (Cat.2 and 3) should be applied for all road surfaces. No correction should be applied for 2-wheelers (Cat.4). The correction coefficient should be applied equally on all octave bands from 63 to 8000 Hz.

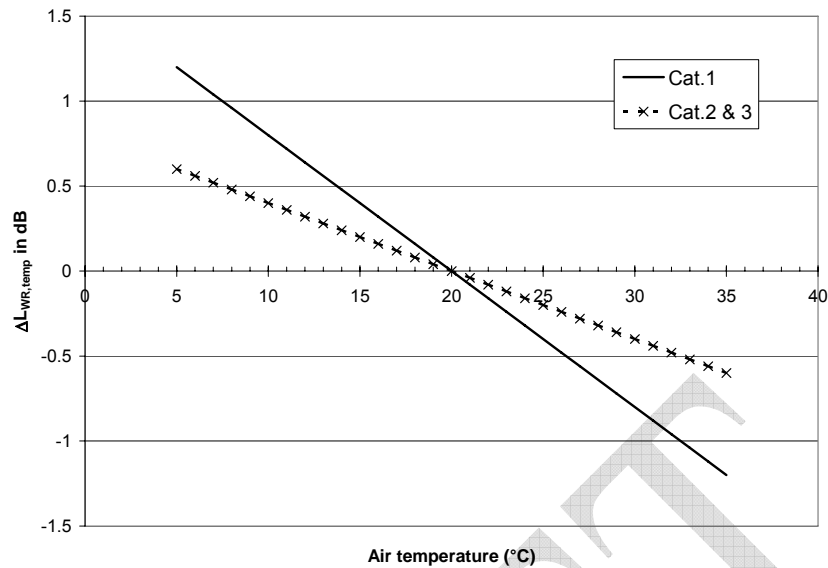


Figure III.5: Semi generic temperature correction.

References

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Appendix III-A (mandatory) - Table of coefficients for sound power emission of road vehicles

The tables below give the coefficients necessary for the calculation of:

- the rolling noise as defined in equation (II-6) (coefficients A_R and B_R)

$$L_{WR} = A_R + B_R \times \lg\left(\frac{v}{v_{ref}}\right) + \Delta L_{studded\ tyres}(v) \quad (III-6)$$

- the correction for studded tyres as define in equation (III-7) (coefficients a and b)

$$\Delta L_{WR,stud} = p_s \times \begin{cases} a + b \times \lg(v/70) & \text{for } 50 \leq v \leq 90 \text{ km/h} \\ a + b \times \lg(90/70) & \text{for } v > 90 \text{ km/h} \\ a + b \times \lg(50/70) & \text{for } v < 50 \text{ km/h} \end{cases} \quad (III-7)$$

- the propulsion noise as defined in equation (III-8) (coefficients A_P and B_P)

$$L_{WP} = A_P + B_P \times \frac{(v - v_{ref})}{v_{ref}} + \Delta L_{WP} \quad (III-8)$$

- and the correction on propulsion noise due to acceleration, as defined in equation (III-10) (coefficient C_P)

$$\Delta L_{WP,acc} = \begin{cases} C_P \cdot a & \text{for } a \geq -1 \text{ m/s}^2 \\ C_P \cdot (-1) & \text{for } a < -1 \text{ m/s}^2 \end{cases} \quad \text{with } |a| \leq a_{max} \quad (III-10)$$

Table III.A.1 – Table of coefficient for **category 1** vehicles (passenger cars)

Octave band center freq. (Hz)	A_R	B_R	A_P	B_P	C_P	a	b
63	79.7	30.0	94.5	-1.3	7.0		
125	85.7	41.5	89.2	7.2	7.0		
250	84.5	38.9	88.0	7.7	5.3		
500	90.2	25.7	85.9	8.0	4.0		
1000	97.3	32.5	84.2	8.0	4.0		
2000	93.9	37.2	86.9	8.0	4.0		
4000	84.1	39.0	83.3	8.0	4.0		
8000	74.3	40.0	76.1	8.0	4.0		

Table III.A.2 – Table of coefficient for **category 2** vehicles (medium heavy vehicles)

Octave band center freq. (Hz)	A_R	B_R	A_P	B_P	C_P
63	84.0	30.0	101.0	-1.9	9.0
125	88.7	35.8	96.5	4.7	9.0
250	91.5	32.6	98.8	6.4	6.6
500	96.7	23.8	96.8	6.5	5.0
1000	97.4	30.1	98.6	6.5	5.0
2000	90.9	36.2	95.2	6.5	5.0
4000	83.8	38.3	88.8	6.5	5.0
8000	80.5	40.1	82.7	6.5	5.0

Table III.A.3 – Table of coefficient for **category 3** vehicles (heavy duty vehicles)

Octave band center freq. (Hz)	A_R	B_R	A_P	B_P	C_P
63	87.0	30.0	104.4	0.0	9.0
125	91.7	33.5	100.6	3.0	9.0
250	94.1	31.3	101.7	4.6	6.9
500	100.7	25.4	101.0	5.0	5.0
1000	100.8	31.8	100.1	5.0	5.0
2000	94.3	37.1	95.9	5.0	5.0
4000	87.1	38.6	91.3	5.0	5.0
8000	82.5	40.6	85.3	5.0	5.0

Table III.A.4 – Table of coefficient for **category 4a** vehicles (Powered 2-wheelers ≤ 50 cc)

Octave band center freq. (Hz)	A_R	B_R	A_P	B_P	C_P
63	0.0	0.0	88.0	4.2	7.0
125	0.0	0.0	87.5	7.4	7.0
250	0.0	0.0	89.5	9.8	5.7
500	0.0	0.0	93.7	11.6	4.0
1000	0.0	0.0	96.6	15.7	4.0
2000	0.0	0.0	98.8	18.9	4.0
4000	0.0	0.0	93.9	20.3	4.0
8000	0.0	0.0	88.7	20.6	4.0

Table III.A.5 – Table of coefficient for **category 4b** vehicles (Powered 2-wheelers > 50 cc)

Octave band center freq. (Hz)	A_R	B_R	A_P	B_P	C_P
63	0.0	0.0	95.0	3.2	7.0
125	0.0	0.0	97.2	5.9	7.0
250	0.0	0.0	92.7	11.9	6.0
500	0.0	0.0	92.9	11.6	4.0
1000	0.0	0.0	94.7	11.5	4.0
2000	0.0	0.0	93.2	12.6	4.0
4000	0.0	0.0	90.1	11.1	4.0
8000	0.0	0.0	86.5	12.0	4.0

Appendix III-B – Procedure applied to derive reference coefficients for sound power emission of road vehicles

To be inserted (from Harmonoise/Imagine report)

Appendix III-C (mandatory) – Spectral distribution of road vehicle noise emission

The spectral distributions to be applied to the sound power emission are described in the following t. The spectral distribution should be applied for each vehicle category to rolling noise and propulsion noise separately.

Table III.C.1 – Spectral distribution for **category 1** vehicles (light vehicles)

1/3 octave band center freq. (Hz)	<i>Rolling noise</i>	<i>Propulsion noise</i>
63		
125		
250		
500		
1000		
2000		
4000		
8000		

Table III.C.2 – Spectral distribution for **category 2** vehicles (small/medium heavy vehicles)

1/3 octave band center freq. (Hz)	<i>Rolling noise</i>	<i>Propulsion noise</i>
63		
125		
250		
500		
1000		
2000		
4000		
8000		

Table III.C.3 – Spectral distribution for **category 3** vehicles (heavy vehicles)

1/3 octave band center freq. (Hz)	<i>Rolling noise</i>	<i>Propulsion noise</i>
63		
125		
250		
500		
1000		
2000		
4000		
8000		

Table III.C.4 – Spectral distribution for **category 4** vehicles (two-wheelers)

1/3 octave band center freq. (Hz)		<i>Propulsion noise</i>
63		
125		
250		
500		
1000		
2000		
4000		
8000		

Appendix III-D (informative) – Source directivity

For noise mapping purposes, road vehicles can be reasonably modelled as omnidirectional point sources. However, in specific cases such as the determination of sound power levels from vehicle pass-by measurements, a fine modelling of noise emission is needed to precisely account as best as possible for all emission and propagation effects. In these cases, the point sources should be assigned both horizontal and vertical directivity.

The reference is the omni-directional sound power level, which yields the correct sound exposure level in the horizontal direction when using the propagation model and integrating during a complete vehicle pass-by. The same vertical directivity is assumed for all horizontal angles.

The directivity correction is composed of a horizontal and a vertical term:

$$\Delta L_{W,dir} = \Delta L_{W,dir,hor} + \Delta L_{W,dir,vert} \quad (III-D.1)$$

The directivity is introduced in the sound power emission calculation by replacing equation (III.2) by the following equation:

$$L_{W,i,m}(v) = 10 \times \lg \left(10^{L_{WR,i,m}(v)/10} + 10^{L_{WP,i,m}(v)/10} \right) + \Delta L_{W,road,i,m}(v) + \Delta L_{W,dir,low,i,m} \quad (III-D.2)$$

However, for road vehicles, the horizontal directivity can reasonably be neglected. Furthermore, in simple cases of general modelling, when no strong heterogeneities in the propagation path exist (for example, no barrier edge in the vicinity), the frequency dependence can be neglected for vertical directivity. The relation can be approached by the following linear function:

$$\begin{aligned} \Delta L_{W,dir} &= -\frac{9}{\pi} \Psi && \text{for category } m = 1 \\ \Delta L_{W,dir} &= -\frac{6}{\pi} \Psi && \text{for category } m = 2 \text{ and } 3 \end{aligned} \quad (III-D.3)$$

Ψ is the vertical propagation angle with respect to the horizontal plane containing the contact points between the vehicle wheels and the road surface (figure III-D.1), $0 \leq \Psi \leq \pi/2$.

This formulation leads to a maximum reduction at an angle of 90° ($\Psi = \pi/2$) of -4.5 dB for category 1 and of -3 dB for category 2 and 3.

For low frequencies, deviating behaviour can be expected due to interference effects, but for L_{Aeq} estimation this effect can be neglected.

No directivity effect is defined for category 4 (two-wheelers) vehicles.

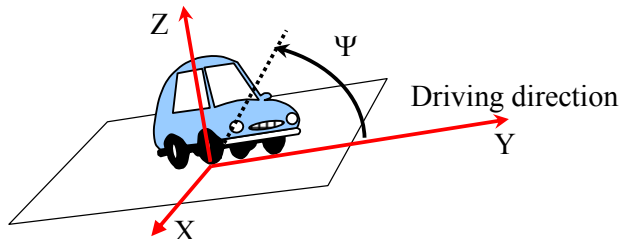


Figure III.D.1 - Geometry for the horizontal and vertical directivity functions.

Appendix III-E (informative) - Examples of correction coefficients for road surface effect

• REFERENCE SURFACE

A “reference cluster” of Dense Asphalt Concrete (DAC) and Stone Mastic Asphalt (SMA) surfaces was set during the HARMONOISE and the IMAGINE research projects [1] [2], among which the virtual reference road surface was defined: this virtual road surface consists of a mixture of DAC 0/11 and SMA 0/11 between 2 and 7 years and in a representative maintenance condition.

For other surfaces within this reference cluster, i.e. belonging to the same “reference” types of surfaces, it is possible to correct the reference level according to the maximum chipping size of the dense surface. The following correction $\Delta L_{WR,road}$ in dB can be applied:

- for light motor vehicles (Cat. 1):

$$\begin{aligned} \circ \text{ DAC: } \Delta L_{WR,road} &= -0.3 + 0.25 \times \frac{D-11}{D_0} \\ \circ \text{ SMA: } \Delta L_{WR,road} &= +0.3 + 0.25 \times \frac{D-11}{D_0} \end{aligned} \tag{III-E.1}$$

where D is the maximum chipping size in mm, $8 \text{ mm} \leq D \leq 16 \text{ mm}$, and $D_0 = 1 \text{ mm}$. The correction is frequency and speed independent. It is applied equally to the coefficient A_R for each frequency band.

- for heavy and medium heavy vehicles (Cat. 2 and 3): no correction is applied for surfaces within the reference cluster.

• OTHER SURFACES

For other road surfaces, the correction on the rolling noise level is given by equation (III-E.2):

$$\Delta L_{W,road} = \alpha_{i,m} + \beta_m \times \lg\left(\frac{v}{v_{ref}}\right) \tag{III-E.2}$$

where : $\alpha_{i,m}$ is the spectral correction in dB at reference speed $v_{ref} = 70 \text{ km/h}$ for category m (1, 2 or 3) and spectral band i (octave bands from 63 to 8000 Hz).

β_m is the speed effect on rolling noise reduction.

Some examples of numerical values obtained on a large set of road surfaces in the Netherlands [1] are given in Table II-E-1 below. It is noted that correction factors for Porous Asphalts are valid for a modelling of sound propagation over a non-porous road surface. The propagation effect is included in the noise emission correction factors.

Table III-E-1 – Road surface correction coefficients for light motor vehicles (Cat.1) (Dutch database [2])

category 1		transversely brushed concrete	concrete with surface dressing 2/4	exposed aggregate concrete	PA ⁽¹⁾ 6/16	2-layer PA ⁽¹⁾ 4/8-11/16	SMA ⁽²⁾ 0/6	surface dressing 4/8
$\alpha_{i,1}$	63Hz							
	125 Hz							
	250 Hz							
	500 Hz							
	1 kHz							
	2 kHz							
	4 kHz							
	8 kHz							
<i>speed index (β_1)</i>		6.0	-5.0	0.0	-11.0	-6.0	-5.0	-4.0
A-weighted correction at 70 km/h		1.4	2.7	1.3	-1.4	-4.6	-1.7	3.4

⁽¹⁾ PA: Porous Asphalt

⁽²⁾ SMA: Stone Mastic Asphalt

Table III-E-2 – Road surface correction coefficients for heavy motor vehicles (Cat.2 and 3) (Dutch database [2])

category 1		transversely brushed concrete	concrete with surface dressing 2/4	exposed aggregate concrete	PAC ⁽¹⁾ 6/16	2-layer PAC ⁽¹⁾ 4/8-11/16	SMA ⁽²⁾ 0/6	surface dressing 4/8
$\alpha_{i,2}$ $\alpha_{i,3}$	63Hz							
	125 Hz							
	250 Hz							
	500 Hz							
	1 kHz							
	2 kHz							
	4 kHz							
	8 kHz							
<i>speed index (β_2, β_3)</i>		12	5	15	-6	-8	0	13
A-weighted correction at 70 km/h		1.1	-0.6	-0.8	-3.8	-5.8	-1.1	-0.7

CHAPTER IV. RAILWAY TRAFFIC NOISE SOURCE EMISSION

IV.1. Source description

IV.1.1. Classification of vehicles

The relevant sound sources contributing to the generation and radiation of railway noise and tram noise consist of various components of the track-train system, namely: the rails and the sleeper or slab, the wheels, the fans, the compressors and the engines, the electrical equipment and the exhaust in the case of diesel-powered locomotives and the superstructure of freight trains. At high speeds, aerodynamics of the bogies and of the pantograph and the train body become relevant as well. Depending on the speed, contributions from these sources change their relative importance, therefore it is not possible to exclude a priori any of these sources. The sources mentioned are mostly dependent on the specific features of single sub-units within a train, rather than being of constant type along the whole train. For this reason, it is appropriate to classify each single sub-unit of a train, and add up the number of single sub-units travelling on a specific track section, rather than using classifications by the whole train type.

Definition of vehicle and train

For the purposes of this noise calculation method, a **vehicle** is defined as any single railway sub-unit of a train (typically a locomotive, a self-propelled coach, a hauled coach or a freight wagon) that can be moved independently and can be detached from the rest of the train. Some specific circumstances may occur for sub-units of a train that are a part of a non-detachable set, e.g. share one bogie between them. For the purpose of this calculation method, all these sub-units are grouped into a single vehicle. Further explanation is given under “Remarks on digit 2 and 3”.

For the purpose of this calculation method, a **train** consists of a series of coupled vehicles.

Table IV-1 defines a common language to describe the vehicle types included in the source database.

In the Table IV-1 1st column, the descriptor used to classify the vehicles reflects only the common commercial classification of the train, and it is to be used as a minimum. Table IV-1 in the other columns presents the relevant descriptors to be used to classify in full the vehicles. Not necessarily all are to be known, although they are descriptors that can help users to decide if the vehicle types contained in the database can be used to simulate the specific vehicle to be assessed. These descriptors correspond to properties of the vehicle which affect the acoustic sound power per metre length of the equivalent sound source modelled.

The number of vehicles for each type shall be determined on each of the track sections for each of the time periods to be used in the noise calculation. It shall be expressed as an average number of vehicles per second that is obtained by dividing the total number of vehicles travelling in a given time period by the duration in seconds of such time period (e.g.: 24 vehicles in 4 hours means 0.0017 vehicles per second). All vehicle types travelling on each track section (defined in the next sub-chapter IV.1.2) shall be used.

Depending on the available information, the classification of the vehicles might be more or less detailed. As explained, a classification drawn from 6 train types (L-Loco, H-High speed passenger, P-Conventional Passenger, F-Freight, C -tram or light metro, O-other types) following a general classification of type of train (or tram/metro) of which the vehicle is part (described by the digit 1) shall be used (commercial classification of trains), though subcategories of vehicle types classified according to the other digits are preferably to be used.

Table IV-1 – Classification and descriptors for railway vehicles

Digit	1	2	3	4	5	6
Descriptor	Train type	Number of axles per vehicle	Brake type	Vehicle type	Wheel diameter	Wheel measure
Explanation of the descriptor	The type of the train is used	the actual number of axles	a letter that describes the brake type	a letter that describes the type	the class of diameter	a letter that describes the noise reduction measure type
Possible descriptors	L Loco	u unknown	u unknown	u unknown	u unknown	n no measure
	H High speed passenger (>200 km/h)	1	c cast-iron block	h high speed vehicle (>200 km/h)	l large, >500 mm	d dampers
	P Conventional Passenger	2	k composite or sinter metal block	M self-propelled passenger coaches	s small < 500 mm	s screens
	F Freight	3	n non tread braked, like disc, drum, magnetic	P hauled passenger coaches		o other
	T Tram or light metro	4		C City tram or light metro self-propelled and non self-propelled coach		
	O Other (i.e. maintenance vehicles...)	et cetera		d diesel loco		
				e electric loco		
				a any generic freight vehicle		
			E, F, G, H, I, K, L, O, R, S, T, U, Z for specific freight vehicles according to UIC-designation for freight vehicles (see figure III-3)			

The parameters associated with the different vehicle types will be found in the CNOSSOS-EU database.

- Generally, if vehicle types are classified by using “u” for most descriptors, an uncertainty is introduced in the calculation since potentially acoustically different

vehicles having different acoustic properties will be grouped under the same vehicle type, though eventually showing different sound contribution because of the differences due to those parameters which are left unknown, and can therefore differ.

- Simplifications can be used by means of grouping different vehicle types to avoid having too many different vehicle types to use in the calculation. Though this can speed up input data acquisition and calculations, it will in general introduce higher discrepancies between real and calculated noise levels.

Remarks on digit 2:

There are vehicle types that remain coupled during their lifetime.

- Many passenger trains consist of 2 or more elements that are never disconnected. These should be normally regarded as one single vehicle (also known as a “multiple unit” if self propelled). An example of a 3-element self-propelled passenger train (multiple units) is shown in figure IV-1.



Figure IV-1: three elements are coupled without the possibility of uncoupling them in normal conditions

- In cases of coupled elements, the number of axles can also be odd: e.g. if a common 2-axle bogie is shared by two coupled elements, the number of axles per vehicle (comprising two coupled elements as explained under the first bullet and in figure IV-1) is 3.
- Some passenger trains, like that illustrated in figure IV-1, have a fractional number of axles per vehicle if the train is not to be treated as a single vehicle. This train has 8 axles on 3 vehicles. In this case, the number should be rounded to the nearest whole number, i.e. $8/3 = 2.7 \sim 3$ axles per unit.
- Also, some freight wagon sets consist of 2 (or more) coupled elements that have one single UIC designation. An example is shown in figure IV-2. As it is not always clear during way-side data collection whether a freight vehicle is part of a set or not, all freight wagon sets have to be considered as separate vehicles.

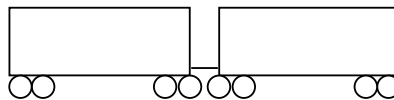


Figure IV-2: two elements that are internationally classified as one single vehicle, but in fact behave acoustically as two separate vehicles

- In the case of calculations, if the number of axles is set unknown, four axles per vehicle shall be assumed.

Remarks on digit 3

The brake type is usually not clear from watching the trains passing by. Braking blocks, if visible, can be cast-iron, composite-blocks, sinter et cetera. Only by using a priori knowledge of the rolling stock can the braking type be identified. In the case of combinations of braking type on the same vehicle, the type that can be expected to affect the wheel tread most is considered dominant ('c' is dominant over 'k', and 'k' is dominant over 'n'). The brake type can also be estimated from measurement of sound or rail vibration and speed given that it is known that different brake types produce different roughness levels and therefore different vibrations and noise are expected.

Remarks on digit 4

Freight trains may take many forms. The first letter of the international UIC designation is used to classify the freight vehicles. The drawings in figure IV-3 provide some assistance in their identification.

In the case of multiple unit passenger trains with powered and unpowered vehicles, *m* is used if the train is analysed as a whole. In the case where unpowered vehicles can be moved independently, *p* should be used while *m* is applied for those that are powered. For instance, in the above example of the 3-element train in figure IV-1, the outer vehicles are motored and therefore named *3nMumn*, and therefore the whole train is also named *3nMumn*.

Remarks on digit 5

The wheel diameter for most passenger and freight trains is usually more than 800 mm (= 1 for "large"). Some flat container carriers and car carriers have smaller wheels. For passenger trains, some "light rail" vehicles may have smaller wheels.

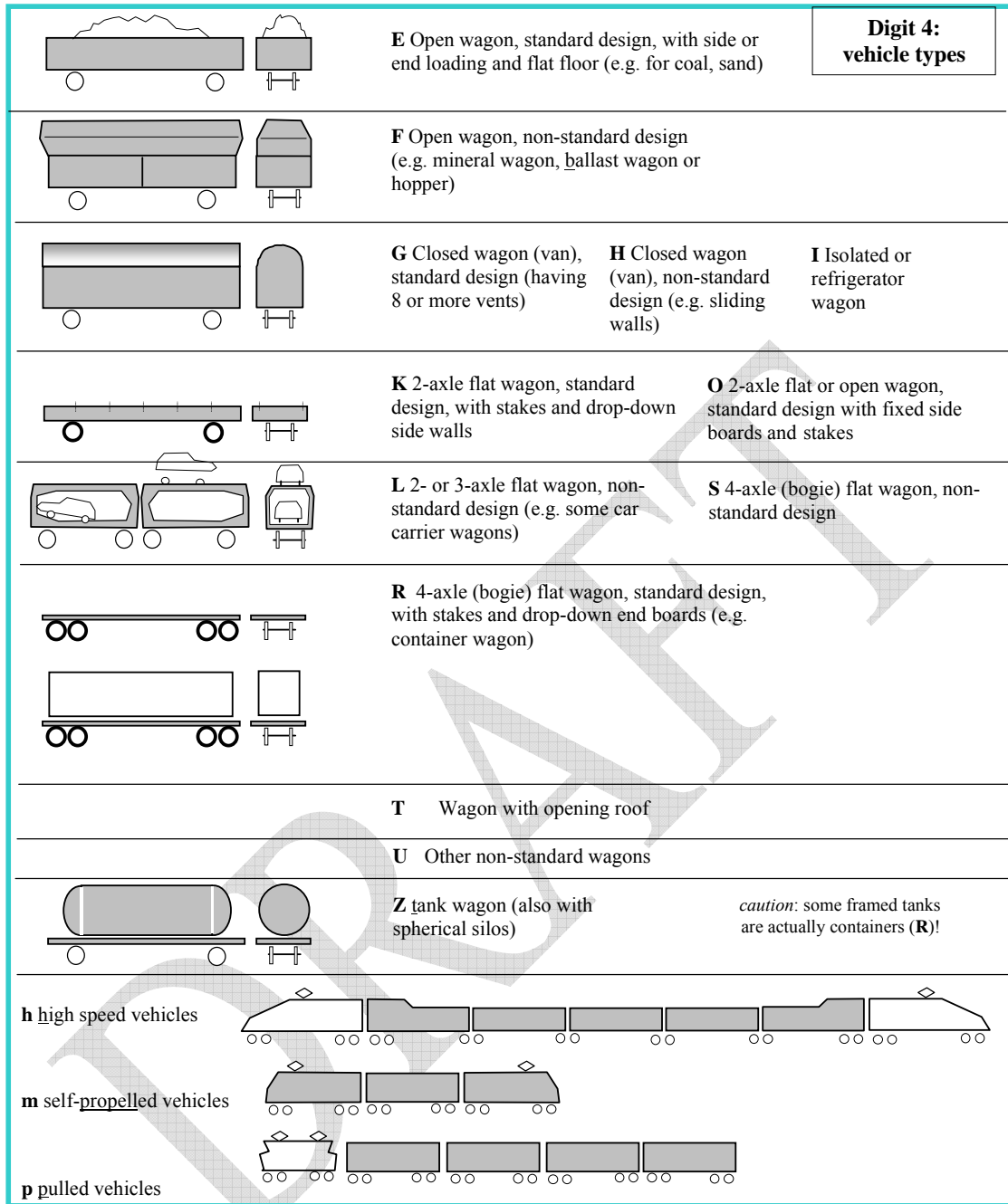


Figure IV-3 – Classification of common vehicle types.

IV.1.2 Classification of tracks and support structure

The existing tracks might differ because of several elements composing and characterising their acoustic properties, which are listed in table IV-2 below. Some of the elements have a large influence on the acoustic properties, while some others have only secondary effect. The most relevant elements influencing the railway noise emission are: railhead roughness, rail pad stiffness, track base, rail type and radius of curvature of the track. Alternatively, the overall track properties can be defined and, in this case, the railhead roughness and the track decay rate according to ISO 3095 are the two acoustically essential parameters, plus the radius of curvature of the track.

A track section is defined as a part of a single track, on a railway line or station or depot, on which the track physical properties and basic components do not change.

Table IV-2 defines a common language to describe the track types included in the source database.

In the Table IV-2 1st column the descriptor used to classify the tracks reflects only the common classification of the tracks, and it is to be used as a minimum. Table IV-2 in the other columns presents the relevant descriptors to be used to classify in full the track types on each railway line section. Not necessarily all are to be known, although they are descriptors that can help users to decide if the track types contained in the database can be used to simulate a specific track section.

Table IV-2 – Classification of the track types.

Digit:	1	2	3	4	5	6	7	8	9	11	12
Descriptor	Track base	Roughness	Rail pad type	Rail Fastener	Sleeper type	Rail type	Sleeper spacing	Additional measures	Rail joints	Curvature	Track dynamic characteristics
Explanation of the descriptor	Type of track base	Indicator for roughness	Presents an indication of the "acoustic" stiffness	Fastener abbreviation	Sleeper type indicator	kg/m	Distance in cm	A letter describing acoustic device	Presence of joints and spacing	Indicate the radius of curvature in m	Decay rates
Codes allowed	B Ballast	E Well maintained and very smooth	S Soft (150-250 MN/m)	S Single pad	W Wood	S (60 kg/m)	S standard (60 cm)	N none	N None	N straight track	U unknown
	S Slab track	M Normally maintained	M Medium (250 to 800 MN/m)	D Double pad	M Concrete mono-block	F (54 kg/m)	O other (specify cm)	D Rail damper	S Single joint or switch	L low (1000-500 m)	O (specify spectrum)
	C Concrete bridge	N Not well maintained	H Stiff (800-1000MN/m)	O Other	B Concrete bi-block	E Embedded rail		B Low barrier	D Two joints or switches per 100 m	M medium (less than 500 m and more than 200 m)	
	E Steel bridge	B Not maintained and bad condition			Z Steel zigzag	O other (specify kg/m)		A Absorber plate on slab track	M More than two joints or switches per 100 meter	H high (less than 200m)	
	T embedded track				S Steel			O Other			
	O Other										

The parameters associated with the different track section types will be found in the CNOSSOS-EU database.

- Generally, if track section types are classified by using "O" for most descriptors and without further specification, an uncertainty is introduced in the calculation since potentially acoustically different track sections having different acoustic properties will be grouped under the same track section type, though eventually showing different sound contribution because of the differences due to those parameters which are left unknown, and can therefore differ.
- Simplifications can be used by means of grouping different track section types to avoid having too many different track section types to use in the calculation. Though

this can speed up input data acquisition and calculations, it will generally introduce higher discrepancies between real and calculated noise levels.

Remarks on digit 1

The classification “C” shall be intended valid for concrete bridge or steel bridge with full-length ballast track.

Remarks on digit 2

The wave-number spectrum of the roughness is obtained according to the standard EN 15610:2009, measured in dB re 1 μm :

- shall be less than the spectrum defined in COMMISSION DECISION of 23 December 2005 concerning the technical specification for interoperability relating to the subsystem ‘rolling stock — noise’ of the trans-European conventional rail system (2006/66/EC) in all the one - third - octave bands or in all the octave bands to be classified as “E”,
- shall be as the approved test track defined in annex A, point A.3 of the standard ISO EN 3095:2005 to be classified as “M”,
- exceeds at least for one third octave band, the limits as set for the approved test track defined in annex A, point A.3 of the standard ISO EN 3095:2005, to be classified as “N”,

exceeds in numerous third octave bands between the one corresponding to 0.005 m to the one corresponding to 0.160 m the spectrum defined as reference spectrum as defined in annex A, point A.3 of the standard ISO EN 3095:2005 to be classified as “B”.

Remarks on digit 12

The spectrum of the decay rate, obtained by means of the standard EN 15461:2008 is a feature which is affected by most of the components already mentioned (corresponding to digits 1, 3, 4, 5, 6, 7, 8), though mainly the track base type, the sleeper type, the rail fastener and the rail pad type. So, in general, it is recommendable to use this parameter to identify the need to introduce a new track section type, if there is a change between two different sections of track base type / sleeper type / rail fastener / rail pad type.

IV.1.3. Number and position of the equivalent sound sources

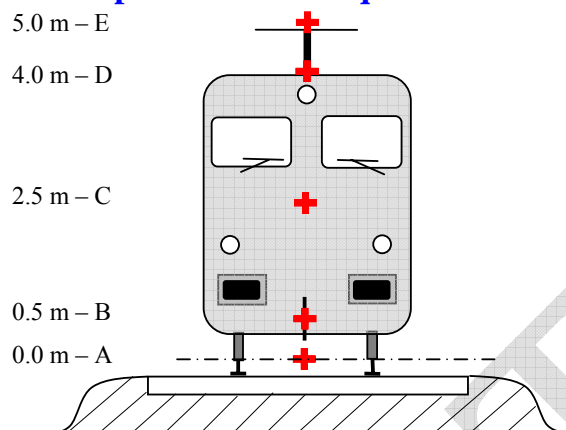


Figure IV-4 – Equivalent noise sources position.

The different equivalent noise line sources are placed at different heights, and at the centre of the track. All heights are referred to the plane tangent to the two upper surfaces of the two rails.

The equivalent sources represent physical sources (index p), which are modelled in the following section IV.2. These physical sources are divided depending on the generation mechanism, and are: 1) **rolling** noise (including not only rail and track base vibration and wheel vibration but also, where present, superstructure noise of the freight vehicles), 2) **traction** noise, 3) **aerodynamic** noise, 4) **impact** noise (from crossings, switches and junctions), 5) **squeal** noise, 6) **braking** noise and noise due to 7) **additional effects** such as bridges and viaducts.

1) The roughness of wheels and rail heads, through three transmission paths to the radiating surfaces (rails, wheels and superstructure), constitute the **rolling noise**. This is divided into two sound sources, allocated to $h = 0.0$ m (radiating surfaces A) to represent the track contribution including the effects of the surface of the tracks, especially slab tracks (in accordance with the propagation part), to $h = 0.5$ m (radiating surface B) to represent the wheel contribution and to $h = 2.5$ m (radiating surface C) to represent the superstructure of the vehicle to noise (in freight trains).

2) The equivalent source heights for **traction noise** vary between 0.5 m (source B), 2.5 m (source C) and 4.0 m (source D) heights, depending on the physical position of the component concerned, and can be evaluated by measurements using special techniques such as microphone array measurements. Sources such as gear transmissions and electric motors will often be at an axle height of 0.5 m (source B). Louvres and cooling outlets can be at various heights; engine exhausts for diesel powered vehicles are often at roof height of 4.0 m (source D). Other traction sources such as fans or diesel engine blocks may be at 2.5 m (source C) or 4.0 m (source D) height. If the exact source height is in between the model heights, the sound energy is distributed proportionately over the nearest adjacent source heights.

For this reason, three source heights are foreseen by the method at 0.5 m (source B), 2.5 m (source C), 4.0 m (source D), and the equivalent sound power associated with each is distributed between the three depending on the specific configuration of the sources on the unit type.

3) **Aerodynamic noise effects** are associated with the source at 0.5 m (representing the shrouds and the screens, source B), and the source at 4.0 m (modelling all over roof apparatus, source D), and the source exclusively representing the pantograph at 5.0 m height, source E).

4) **Impact noise** is associated with the sources at 0.0 m and 0.5 m (source B).

5) **Squeal noise** is associated with the sources at 0.0 m (source A) and 0.5 m (source B).

6) **Braking noise** is associated with the source at 0.5 m (source B).

7) **Bridge noise** is associated with the source at 0.0 m (source A).

N.B.: *In the following, the source heights are denoted by the index h , and each physical source by the index p , so, there can exist more source heights for the same physical source (e.g.: rolling noise at 0.0 m and 0.5 m) and different physical sources for the same source height (e.g.: rolling noise at 0.5 m and squeal noise at 0.5 m). Moreover, further on the directivity coefficient is introduced, which depends on the source type and source height, therefore, is linked both to the p and the h coefficients.*

In several situations, detailed information on sound power contribution of the different sources at different heights is missing. As a minimum it is required to use the following two sources: Source B (0.5 m) for rolling noise, aerodynamic noise, impact noise (only for jointed tracks), squeal noise and traction noise, and Source D (4.0 m) for aerodynamic noise and traction noise. Impact (except for jointed tracks), braking and additional effects are neglected. The error introduced by misplacing the sound power initially defined by the formulas for other appropriate source heights (Source A, Source C, Source E) is considered acceptable in this approximation.

IV.2. Sound power emission

IV.2.1. General equations

Individual vehicle

The model for railway traffic noise, analogously to the road traffic noise, describes the noise sound power emission of a specific combination of vehicle type and track type, which fulfils a series of requirements described in the vehicle and track classification, in terms of sound power level per each vehicle ($L_{W,0}$). This description is consistent with the propagation calculation scheme detailed in Chapter VI.

Traffic flow

The noise emission of a traffic flow on each track is to be represented to the purpose of the calculation (Chapter VI) by a set of h line sources characterised by its time averaged sound power per 1-meter length. This corresponds to the sum of the sound emission due to the

individual vehicles pass-by in the traffic flow, and, in the specific case of stationary vehicles, taking into account the time spent by the vehicles in the considered railway section.

The level of average sound power per track meter length, due to all vehicles pass by is defined:

- for each frequency band (*i*),
- for each track section (*j*) with the same track type (see table IV -2),
- for each given source height (*h*) (sources at 0.0m *h*=1, at 0.5m *h*=2, at 2.5m *h*=3, at 4.0m *h*=4, at 5m *h*=5),

and is the energy sum of all contributions from all vehicles running on the specific *j*-th track section. These contributions are:

- from all vehicle types (*t*)
- at their different speeds (*s*)
- under the particular running conditions (constant speed, decelerating or accelerating) (*r*)
- for each physical source type (rolling, impact, squeal, braking, traction, aerodynamic, and additional effects sources such as e.g.: bridge noise) (*p*)

To calculate the average directional sound power per meter length (input to the calculation part) due to the average mix of traffic on the *j*-th track section, the following is used:

$$L_{W',eq,T,dir} = 10 \cdot \lg \left(\sum_{x=1}^X 10^{L_{w',eq,line,x}/10} \right) \quad (IV-1)$$

with:

T = reference time period for which the average traffic is considered

X = total number of existing combinations of *i*, *t*, *s*, *r*, *p*, for each *j*-th track section.

t = index for vehicle types on the *j*-th track section (see Table IV-1)

s = index for train speed: there will be as many indexes as the number of different average train speeds on the *j*-th track section

r = index for running conditions: 1 (for constant speed), 2 (for decelerating), 3 (for accelerating), 4 (idling)

p = index for physical source types: 1 (for rolling and impact noise), 2 (curve squeal), 3 (braking noise), 4 (traction noise), 5 (aerodynamic noise), 6 (additional effects)

L_{w',eq,line,x} = *x*-th equivalent line directional source sound power per meter of one combination of *i*, *t*, *s*, *r*, *p* on each *j*-th track section

If a steady flow of *Q* vehicles per unit time is assumed, with an average speed *v*, on average at each moment in time there will be an equivalent number of *Q/v* vehicles per unit length of the

railway section. When integrating¹⁰, the noise emission of the vehicle flow in terms of an equivalent line source strength (time averaged directional sound power level per unit length) $L_{W',eq,line}$ (expressed in dB/m (re. 10^{-12} W)) is defined by:

$$L_{W',eq,line}(\psi, \phi) = L_{W,0,dir}(\psi, \phi) + 10 \times \lg\left(\frac{Q}{1000 v}\right) \quad (\text{for } r \neq 4) \quad (IV-2)$$

Where:

- Q is the average number of vehicles per hour on the j -th track section for vehicle type t , average train speed s and running condition r [1/s]
- v is their speed in [km/h] on the j -th track section for vehicle type t and average train speed s
- $L_{W,0,dir}$ is the *directional sound power level* of the specific noise (rolling, impact, squeal, braking, traction, aerodynamic, other effects) of a single vehicle in the directions ψ, ϕ defined with respect to the vehicle direction of movement (see figure IV-5), and is:

And, in the case of stationary source like during idling, it is assumed that the vehicle will remain for an overall time T on a location within a track section which length is L . Being T_{ref} the reference time period for the noise assessment (e.g.: 12 hours, 4 hours, 8 hours), the time averaged directional sound power level per unit length on that track section is defined by:

$$L_{W',eq,line}(\psi, \phi) = L_{W,0,dir}(\psi, \phi) + 10 \times \lg\left(\frac{T}{T_{ref} L}\right) \quad (\text{for } r=4) \quad (IV-3)$$

$$L_{W,0,dir}(\psi, \phi) = L_{W,0} + \Delta L_{W,dir,vert} + \Delta L_{W,dir,hor} \quad (IV-4)$$

Where:

- $\Delta L_{W,dir,vert}$ is the vertical directivity correction (dimensionless) function of ψ (figure IV-5)
- $\Delta L_{W,dir,hor}$ is the horizontal directivity correction (dimensionless) function of ϕ (figure IV-5)

¹⁰ The exact explanation of how this formula correctly represent the reality and can be alternatively integrated in the time or in the space is explained in the document “sound power and sound pressure definitions in CNOSSOS-EU”

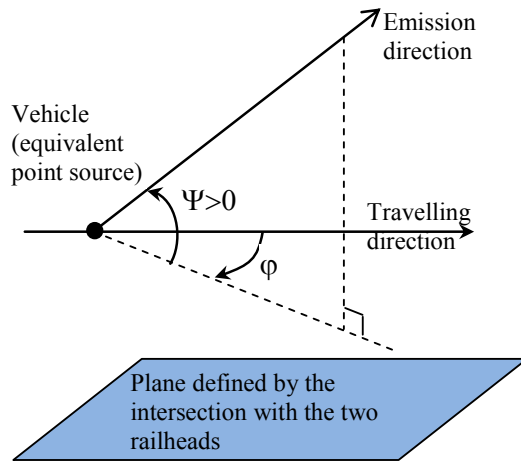


Figure IV-5: Geometrical definition

For the purpose of the calculations, the source strength is then specifically expressed in terms of directional sound power per 1 m length of track $L_{W,0,tot,dir}$, to account for the directivity of the sources in their vertical and horizontal direction, by means of the additional corrections:

Several $L_{W,0,dir}(\psi, \varphi)$ are considered for each vehicle-track-speed-running condition combinations:

- for third octave frequency band (*i*),
- for each track section (*j*) (see table IV-2),
- source height (*h*) (sources at 0.0m *h*=1, at 0.5m *h*=2, at 2.5m *h*=3, at 4.0m *h*=4, at 5m *h*=5)
- directivity (*d*) of the source.

As a minimum, a set of $L_{W,0,dir}(y, j)$ are considered for each vehicle-track-speed-running condition combinations considering full octave bands, each track section, the heights corresponding to *h*=2 and *h*=4 and the directivity.

N.B.: In the rest of this chapter, all the sound power levels and correction coefficients are intended to be expressed for each 1/3-octave band *i* (*i* = 1 to 27) in the range [25 Hz – 10 kHz] and each track section *j*. Moreover, by default, all the subscripts are implicit in all the indicators: they are omitted to improve the readability of the text.

Note: The equation (IV-1) is the general equation: it shall be remarked that several combinations of indexes may not correspond to an existing equivalent sound source, e.g.: vehicle type *u*=1 may be only for constant speed (*k*=1) therefore the combination of indexes (*u,k*)=(1,2) does not correspond to an existing equivalent sound source. Also, the directivity may be not the same for all sources at a given position A, B, C, D or E.

IV.2.2. Rolling noise

The vehicle contribution and the track contribution to rolling noise are separated into four essential elements: wheel roughness, rail roughness, vehicle transfer function to the wheels and to the superstructure (vessels) and track transfer function. Wheel and rail roughness represent the cause of the excitation of the vibration at the contact point between the rail and the wheel, and the transfer functions are two empirical or modelled functions that represent the entire complex phenomena of the mechanical vibration and sound generation on the surfaces of the wheel, the rail, the sleeper and the track substructure. This separation reflects the physical evidence that roughness present on a rail may excite the vibration of the rail, but will also excite the vibration of the wheel, and vice versa. Not including one of these four parameters would prevent the decoupling of the classification of tracks and trains.

IV.2.2.1. Wheel and rail roughness

Rolling noise is mainly excited by rail and wheel roughness in the wavelength range from 5-500 mm.

Definition

The roughness level L_r is defined as ten times the logarithm to the base ten of the square of the mean square value r^2 (MS) of the roughness of the running surface of a rail or a wheel in the direction of motion (longitudinal level) measured in μm over a certain rail length or the entire wheel diameter), divided by the square of the reference value r_0^2 :

$$L_r = 10 \times \lg \left(\frac{r}{r_0} \right)^2 \quad \text{dB} \quad (IV-5)$$

where $r_0 = 1 \mu\text{m}$

r = rms of the vertical displacement difference of the contact surface to the mean level

The roughness level L_r is typically obtained as a wavenumber λ spectrum, and it must be converted to a frequency spectrum $f = v/\lambda$, where f is the centre band frequency of a given third octave band in Hz, λ is the wavelength in m, and v is the train speed in m/s. The roughness spectrum as a function of frequency shifts along the frequency axis for different speeds. In general cases, after conversion to frequency spectrum by means of the speed, it is necessary to obtain new 1/3 octave band spectra values averaging amongst two corresponding 1/3 octave bands in the wavelength domain. To estimate the total effective roughness frequency spectrum corresponding to the appropriate train speed it is required to average energetically and proportionally the two corresponding 1/3 octave bands defined in the wavelength domain.

The rail roughness level (track side roughness) for the i -th wavenumber band is defined as $L_{r,TR,i}$

In analogy, **the wheel roughness level** (vehicle side roughness) for the i -th wavenumber band is defined as $L_{r,VEH,i}$

The total and effective roughness level for wavenumber band i ($L_{R,tot,i}$) is defined as the energy sum of the roughness levels of the rail and that of the wheel plus the $A_3(\lambda)$ contact filter to consider the filtering effect of the contact patch between the rail and the wheel, and is, in dB:

$$L_{R,TOT,i} = 10 \cdot \log_{10} \left(10^{L_{r,TR,i}/10} + 10^{L_{r,VEH,i}/10} \right) + A_{3,i} \quad (IV-6)$$

where $A_{3,i}$ is the contact filter expressed as a function of the i -th wavenumber band corresponding to the wavelength λ .

The contact filter depends on the rail and wheel type and the load, and for some specific common cases, it is presented in Appendix IV-A.

It is practical to work with total effective roughness level as it is related directly to the real excitation. The total effective roughness $L_{R,TOT,i}$ (for wave-number band i) can be derived from rail vibration measurements or from direct roughness measurement on wheels and rails and a contact patch filter. The total effective roughness for the j -th track section and each t -th vehicle type at its corresponding v_{ts} speed is used in the method. Indirect roughness measurements can also be performed (e.g.: noise measurement under a special reference vehicle to assess the trackside roughness over long distances) to get effective rail roughness. Also, wheel roughness can be derived from databases on wheelsets based on the braking system used.

IV.2.2.2. Vehicle and track transfer function

Two speed-independent transfer functions, $L_{H,tr,i}$ and $L_{H,veh,i}$, are defined for each j -th track section and each t -th vehicle type. They respectively relate the total effective roughness level with the sound power of the track and the wheels. These functions can be obtained from specific measurements but are also tabulated for some common cases in Appendix IV-B.

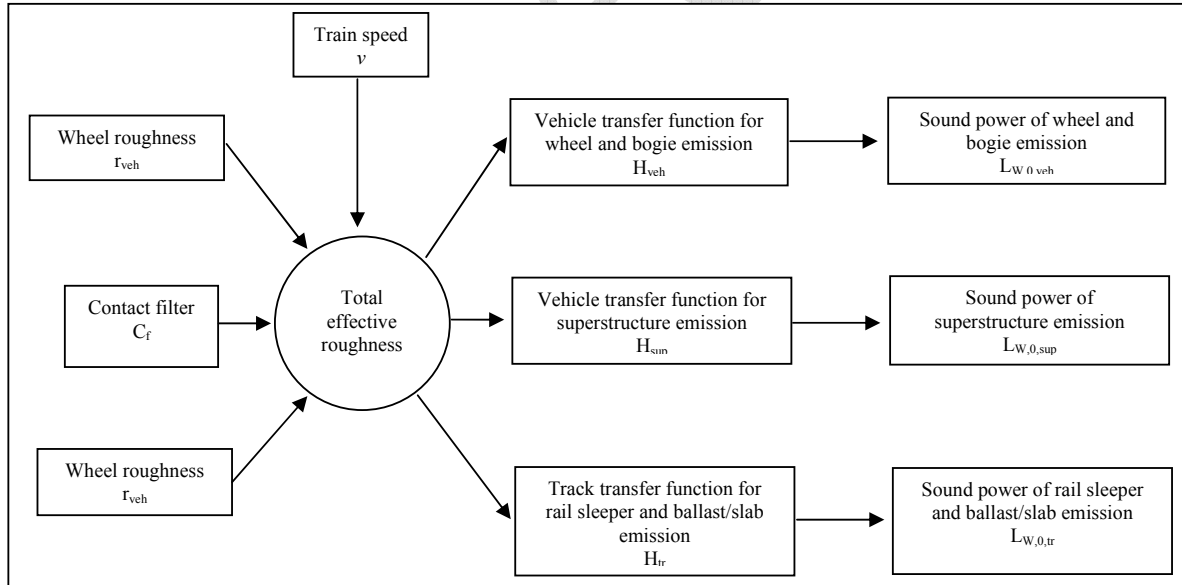


Figure IV-6: Scheme of the use of the different roughness and transfer function definitions.

For rolling noise, therefore, the contributions from the track and from the vehicle are fully described by these transfer functions, and by the total effective roughness level.

For sound power per vehicle the rolling noise is calculated at rail head height (track contribution, at source A at 0.0 m), at axle height (vehicle contribution at source B at 0.5 m above rail head) and at superstructure height (vehicle contribution at source C at 2.5 m above

rail head), and has as an input the total effective roughness level $L_{R,TOT}$ (see equation (IV-6)) as a function of the vehicle speed v , the track and vehicle transfer functions $L_{H,TR}$ and $L_{H,VEH}$ and the total number of axles N_a :

for $h = 1$:

$$L_{W,0} = L_{R,TOT} + L_{H,TR} + 10 \times \lg(N_a) \quad \text{dB} \quad (IV-7)$$

for $h = 2$:

$$L_{W,0} = L_{R,TOT} + L_{H,VEH} + 10 \times \lg(N_a) \quad \text{dB} \quad (IV-8)$$

for $h = 3$:

$$L_{W,0} = L_{R,TOT} + L_{H,VEH,SUP} + 10 \times \lg(N_a) \quad \text{dB} \quad (IV-9)$$

where N_a is the number of axles per vehicle for the t -th vehicle type

It is possible to use a reduced number of running conditions. As a minimum it is required to consider one running condition (constant speed), two transfer functions $L_{H,TR,i}$ and $L_{H,VEH,i}$, and, consistently with the other minimum requirements (i.e., on vehicle type, track type, number of source heights), to define only one total effective roughness level spectra for each combination of the six vehicle classes (defined by means of train type) and the six track classes. Also, in this minimum requirements implementation, the sound powers calculated by means of (IV-7), (IV-8) and (IV-9) shall be added up and attributed at $h=2$. A minimum speed of 50 km/h (30 km/h only for trams and light metro) is to be used to determine the total effective roughness and therefore the sound power of the vehicles (this speed shall not affect the vehicles flow) to compensate for the potential error introduced by the simplification of rolling noise definition, braking noise and impact noise from crossings and switches.

IV.2.3. Impact noise (crossings, switches and junctions)

Impact noise can be caused by crossings, switches and rail joints or points. It can vary in magnitude and can dominate over rolling noise. As it is often localised, it has to be taken into account when choosing track segmentation. If present, impact noise is included in the rolling noise term by (energy) adding a supplementary fictitious impact roughness level to the total effective roughness level on each specific j -th track section where it is present. In this case a new $L_{R,TOT+IMPACT,i}$ should be used in place of the $L_{R,TOT,i}$ according to paragraph III.2.2 and it will be:

$$L_{R,TOT+IMPACT} = 10 \times \lg(10^{L_{R,TOT}/10} + 10^{L_{R,IMPACT}/10}) \quad \text{dB} \quad (IV-10)$$

$L_{R,IMPACT,i}$ is a third octave band spectrum (as a function of frequency). To obtain this frequency spectrum, a spectrum is given as function of wavelength λ in Appendix IV-C, and shall be converted to the required spectrum as function of frequency using the relation $\lambda = v_s/f$, where f

is the third octave band centre frequency in Hz and v_{ts} is the s -th vehicle speed of the t -th vehicle type in m/s.

Impact noise will depend on the severity and number of impacts per unit length or joint density n_j , so in case multiple impacts are given, the impact roughness level to be used in the equation (IV-10) is to be calculated as follows:

$$L_{R,IMPACT} = L_{R,IMPACT-SINGLE} + 10 \times \lg\left(\frac{n_j}{0.01}\right) \text{ dB} \quad (IV-11)$$

where $L_{R,IMPACT-SINGLE,i}$ is the impact roughness level as given for a single impact in Appendix IV-C and n_j is the joint density.

The default impact roughness level is given for a joint density $n_j = 0.01 \text{ m}^{-1}$, which is 1 impact per 100 m track. Situations with different numbers of joints can be approximated by adjusting the joint density n_j . It should be noted that when modelling the track layout and segmentation, the rail joint density should be taken into account, i.e. it may be necessary to take a separate source segment for a stretch of track with more joints. The $L_{W,0}$ of track, wheel/bogie and superstructure contribution are incremented by means of the $L_{R,IMPACT,i}$ for +/- 50 m before and after the rail joint. In case of series of joints, the increase is extended between -50 m before the 1st joint, and +50 m after the last joint.

The applicability of these sound power spectra should be normally verified on site.

As a minimum, impact noise has to be considered for jointed tracks, and a default n_j of 0.01 is to be used. For impact noise due to switches, crossings and joints in track sections with speed less than 50 km/h (30 km/h only for trams and light metro), if the minimum speed of 50 km/h (30 km/h only for trams and light metro) is used to include more effects accordingly to the description of rolling noise chapter, modelling can be avoided.

IV.2.4. Squeal

Curve squeal is a special source that is only relevant for curves and is therefore localised. As it can be significant, an appropriate description is required. Curve squeal is generally dependent on curvature, friction conditions, train speed and track-wheel geometry and dynamics. The emission level to be used is determined for curves with radius below or equal to 700 m and for sharper curves and branch-outs of points with radii below 300 m. The noise emission should be specific to each type of rolling stock, as certain wheel and bogie types may be significantly less prone to squeal than others. The emission level $L_{W,0}$ corresponding to the squeal is given as a function of speed and curve radius, depending on the track (curve or points) and the vehicle type. The source height is at axle height (source B at 0.5 m corresponding to index $h=2$).

Squeal noise sound power is given for different curve radii and can be approximated by the following numerical relationship which will give an equivalent -per vehicle - sound power:

$$L_{W,0} = L_{W,0}(R_0) - 20 \cdot \log_{10}\left(\frac{R_j}{R_0}\right) \text{ dB} \quad (IV-12)$$

where:

R_0 is the reference radius of track curvature corresponding to 500 m,

R_j is the radius of curvature of the j -th track section,

$L_{W,0}(R_0)$ is a tabulated reference value for squeal noise for the reference radius of curvature R_0 (Appendix IV-D)

The applicability of these sound power spectra should be normally verified on site, specifically for trams.

At a minimum, to avoid using the full formulation, squeal noise has to be considered by adding 8 dB for $R < 300$ m and 5 dB for $300 \text{ m} < R < 500 \text{ m}$ to the rolling noise sound power spectra for all frequencies.

IV.2.5. Braking noise

Deceleration noise consists of braking noise at normal speeds (often broadband) and brake squeal, which usually sets in at lower speeds. The energy sum is taken for braking and brake squeal (if relevant) to give the overall deceleration noise sound power spectrum as a function of speed. The applicability of these sound power spectra should normally be verified on site.

IV.2.5.1. Broadband braking noise

For braking noise with speed dependency, especially broadband braking noise, the following expression is used which will give an equivalent -per vehicle - sound power:

$$L_{W,0,bb} = L_{W,0,ref,bb}(v_0) + C_{brake} \cdot \log_{10}\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \quad (IV-13)$$

where:

$L_{W,0,ref,bb}(v_0)$ is a tabulated reference value for broadband braking noise for given speed v_0

C_{brake} is the speed dependency factor.

IV.2.5.2. Brake squeal

For brake squeal:

$$L_{W,0,bs} = L_{W,0,ref,bs} + 10 \times \lg(d_{squeal}) \text{ dB} \quad (IV-14)$$

where:

$L_{W,0,ref,bs}$ is a tabulated reference value for braking squeal

d_{squeal} is the tabulated duration correction

Overall, the braking noise is attributed at the source B at height 0.5 m and is obtained as:

$$L_{W,0} = 10 \times \lg\left(10^{L_{W,0,bb}/10} + 10^{L_{W,0,bs}/10}\right) \text{ dB} \quad (IV-15)$$

The coefficients for broadband braking noise and those for brake squeal are tabulated in Appendix IV-E.

As a minimum, brake noise is neglected for speeds more than 50 km/h (30 km/h only for trams and light metro) and included for lower speeds by the definition of a minimum speed of 50 km/h (30 km/h only for trams and light metro), accordingly to the description of rolling noise chapter.

IV.2.6. Traction noise

Traction noise is generally specific for each characteristic operating condition: constant speed (including deceleration, when it is assumed the same noise as for constant speed), acceleration and idling. The source strength is therefore here modelled for each operating condition. This results in the quantities $L_{W,0,const} = L_{W,0,dec}$ (for constant speed and decelerating respectively) $L_{W,0,acc}$ for acceleration, and $L_{W,0,idling}$ for idling. The appropriate one is to be used according to the operating condition of the train in each j -th track segment.

The $L_{W,0,idling}$ is expressed as a static noise source in the idling position, for the duration of the idling condition, and to be used modelled as a fixed point source (by means of formula (IV-3)).

These quantities can either be obtained from measurement of all sources at each operating condition, or the partial sources can be characterised individually, determining their parameter dependency and relative strength. This may be done by means of measurements on a stationary vehicle, by varying shaft speeds of the traction equipment, following ISO 3095. As far as relevant, several traction noise sources have to be characterised which might not be all directly train speed dependent:

- Noise from the power train, such as diesel engine (including inlet, exhaust and engine block), gear transmission, electrical generators, mainly dependent on engine round per minute speed (rpm), and electrical sources such as converters, which may be mostly load dependent;
- Noise from fans and cooling systems, depending on fan rpm; in some cases fans can be directly coupled to the driveline;
- Intermittent sources such as compressors, valves and others with a characteristic duration of operation and corresponding duty cycle correction for the noise emission.

As each of these sources can behave differently at each operating condition, the traction noise must be specified accordingly. The source strength is obtained from measurement under controlled conditions. In general, locomotives will tend to show more variation in loading as the number of vehicles hauled and thereby the power output can vary significantly, whereas fixed train formations such as electric motored units (EMUs), diesel motored units (DMUs) and high speed trains have a more well defined load.

There is no a priori attribution of the source sound power to the source heights, and this choice shall be made depending on the specific noise and vehicle assessed. It is here modelled to be at source B (0.5 m height), at source C (2.5 m height) and at source D (4.0 m height). In Appendix IV-F, the standard proportion of traction noise to be attributed to the two sources heights is given.

As a minimum, traction noise shall be included considering only maximum load condition (the values for accelerating speed are to be used), and the sound power corresponding to sources C and D shall be attributed all at the source D (4.0 m).

IV.2.7. Aerodynamic noise

Aerodynamic noise is only relevant at high speeds and therefore it should first be verified whether it is actually necessary for application purposes. If the rolling noise roughness and transfer functions are known, it can be extrapolated to higher speeds and a comparison can be made with existing high speed data to check whether higher levels are produced by aerodynamic noise. If train speeds on a network are above 200 km/h but limited to 250 km/h, in some cases aerodynamic noise may not be necessary to include, depending on vehicle design.

The aerodynamic noise contribution is given as a function of speed and source height, for height at source B (0.5 m) at source D (4.0 m) and at source E (5.0 m):

$$L_{w,0} = L_{w,0}(v_0) + \alpha_2 \times \lg\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \quad (IV-16)$$

$$L_{w,0} = L_{w,0}(v_0) + \alpha_4 \times \lg\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \quad (IV-17)$$

$$L_{w,0} = L_{w,0}(v_0) + \alpha_5 \times \lg\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \quad (IV-18)$$

where:

v_0 is a speed at which aerodynamic noise is dominant and is fixed at 250 km/h,

α_2 is a coefficient determined from 2 or more measurement points, for sources at known source heights, for example, the first bogie (height = 0.5 m),

α_4 is a coefficient determined from 2 or more measurement points, for sources at known source heights, for example, the pantograph recess heights (height = 4m),

α_5 is a coefficient determined from 2 or more measurement points, for sources at known source heights, for example, the pantograph recess heights (height = 5m).

Example coefficients for α_2 , α_4 , α_5 are given in Appendix IV-G.

As a minimum, aerodynamic noise shall be included for speeds equal to or more than 200km/h considering in full the above description, but the sound power corresponding to sources D and E shall be attributed all at the source D (4.0 m).

IV.2.8. Source directivity

The horizontal directivity $\Delta L_{W,dir,hor}$ in dB is given in the horizontal plane and by default can be assumed to be a dipole for rolling, impact (rail joints etc), squeal, braking, fans and aerodynamic effects, given for each i -th frequency by:

$$\Delta L_{W,dir,hor,i} = 10 \times \lg(0.01 + 0.99 \cdot \sin^2 \varphi) \quad (IV-19)$$

The vertical directivity $\Delta L_{W,dir,ver}$ in dB is given in the vertical plane for sources A (0.0 m), B (0.5 m), as a function of the centre band frequency of each i -th third octave band:

$$\Delta L_{W,dir,ver,i} = \left(\left[\frac{40}{3} \times \left[\frac{2}{3} \times \sin(2 \cdot \psi) - \sin \psi \right] \times \lg \left[\frac{f_{c,i} + 600}{200} \right] \right] \right) \quad (IV-20)$$

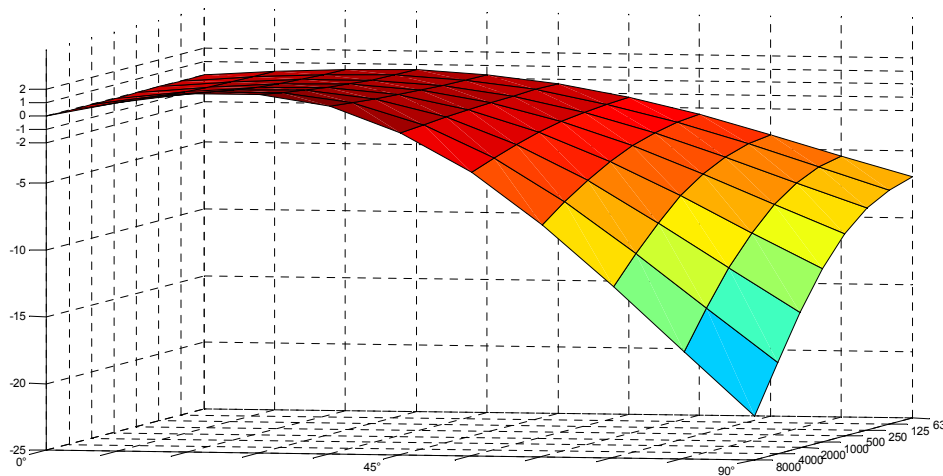


Figure III-7: Vertical directivity correction as function of angles and frequencies.

For source E (5.0m),

$$\Delta L_{W,dir,ver,i} = 10 \lg(\cos^2 \Psi) \quad \text{for } \psi < 0 \quad (IV-21)$$

$$\Delta L_{W,dir,ver,i} = 0 \quad \text{elsewhere} \quad (IV-22)$$

Directivity $\Delta L_{dir,ver}$ is not considered for sources C (2.5 m) and D (4.0 m), as omnidirectionality is assumed for these sources in this direction.

For the sources to which it applies, directivity shall always be considered.

IV.3. Additional effects

IV.3.1. Correction for structural radiation (bridges and viaducts)

In the case where the track section is on a bridge, it is necessary to consider the additional noise generated by the vibration of the bridge, as a result of the excitation of the presence of the train on it. Because it is not simple to model the bridge emission as an additional source, given the complex shapes of the bridges, an increase in the rolling noise is used to account for the bridge noise. The increase is modelled for the A-weighted overall level exclusively and corresponds to a fixed increase in the noise sound power. The sound power of the rolling noise only is modified so as to consider the correction and the new $L_{W,0,rolling-and-bridge}$ is to be used instead of : $L_{W,0,rollingonly}$

$$L_{W,0,rolling-and-bridge} = L_{W,0,rollingonly} + C_{bridge} \text{ dB} \quad (IV-23)$$

where C_{bridge} is a constant that can be obtained depending on the bridge type from the table in Appendix III-H, and $L_{W,0,rollingonly}$ is the rolling noise sound power on the given bridge depending on the vehicle and track properties only.

The structural radiation as presented above shall always be considered.

IV.3.2. Correction for other railway related noise sources

Various sources like depots, loading/unloading areas, stations, bells, station loudspeakers can be present and are associated with the railway noise. These sources are to be treated as industrial noise sources (fixed noise sources) and therefore for a correct modelling the chapter V shall be addressed.

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Appendix IV-A

The contact filter depends on the rail and wheel type and the load, and for some specific common cases, it is presented here.

Wavelength [cm]	360mm / 50 kN	680mm / 50 kN	920mm / 25 kN	920 mm / 50 kN	920 mm / 100 kN
1	-8.4	-12	-12	-12	-12
0.8	-12	-12.5	-12.6	-13.5	-14
0.63	-11.5	-13.5	-13.5	-14.5	-15
0.5	-12.5	-16	-14.5	-16	-17
0.4	-13.9	-16	-16	-16.5	-18.4
0.315	-14.7	-16.5	-16.5	-17.7	-19.5
0.25	-15.6	-17	-17.7	-18.6	-20.5
0.2	-16.6	-18	-18.6	-19.6	-21.5
0.16	-17.6	-19	-19.6	-20.6	-22.4
0.125	-18.6	-20.2	-20.6	-21.6	-23.5
0.1	-19.6	-21.2	-21.6	-22.6	-24.5
0.08	-20.6	-22.2	-22.6	-23.6	-25.4
0.063	-21.6	-23.2	-23.6	-24.6	-26.5
0.05	-22.6	-24.2	-24.6	-25.6	-27.5
0.04	-23.6	-25.2	-25.6	-26.6	-28.4

Appendix IV-B

Two speed-independent transfer functions, $L_{H,tr,i}$ and $L_{H,veh,i}$, are defined for each j -th track section and each t -th vehicle type. They respectively relate the total effective roughness level with the sound power of the track and the wheels. These functions can be obtained from specific measurements but are also tabulated for some common cases here.

freq	L _{h,tr,i}										
	Monoblok on soft rail pad	Monoblok on medium stiffness rail pad	Monoblok on hard rail pad	Biblok on soft rail pad	Biblok on medium stiffness rail pad	Biblok on hard rail pad	Wooden sleepers	Wheel with diameter 920mm	Wheel with diameter 840mm	Wheel with diameter 680mm	Wheel with diameter 1200m
25	35.1	32.1	31.1	32.1	31.1	31.1	26.1	78.1	78.1	78.1	78.1
32	41.6	38.6	37.6	38.6	37.6	37.6	32.6	77.8	77.8	77.8	77.8
40	49.4	46.4	45.4	46.4	45.4	45.4	40.4	77.9	77.9	77.9	77.9
50	56.2	53.8	53.0	53.8	52.9	52.7	46.9	77.2	77.2	77.2	77.2
63	61.9	60.4	59.8	59.2	58.7	58.5	53.6	79.5	79.5	79.5	79.5
80	63.6	62.9	62.7	60.7	60.5	60.4	56.3	82.1	82.1	82.1	82.1
100	71.0	71.9	72.3	67.4	67.6	67.6	65.9	82.0	82.0	82.0	82.0
125	78.3	80.0	80.7	74.5	74.9	75.0	74.2	83.0	82.5	82.5	82.5
160	82.4	83.9	84.6	79.1	79.7	80.0	77.7	82.1	81.1	81.1	81.1
200	85.6	87.2	87.9	83.2	85.0	85.8	78.6	85.5	83.6	83.4	84.0
250	83.3	84.7	85.4	81.3	83.4	84.4	75.6	88.8	85.6	85.0	89.1
315	86.7	87.3	87.8	84.8	85.3	85.9	81.0	89.0	87.1	87.2	89.6
400	92.0	91.4	91.8	89.4	87.2	87.7	90.0	87.4	88.3	90.6	88.3
500	96.7	95.3	95.5	94.2	90.3	90.5	96.7	84.8	86.9	89.9	86.1
630	101.1	99.3	98.9	99.4	95.7	95.0	100.6	90.1	91.2	92.2	91.0
800	98.7	96.4	95.0	98.7	95.3	92.6	97.5	91.1	90.2	89.6	90.2
1000	103.0	100.3	98.4	103.8	100.6	97.0	101.3	92.3	90.4	87.8	91.0
1250	107.7	105.4	103.6	108.3	105.7	102.8	105.9	97.3	95.6	90.1	97.4
1600	110.7	109.0	107.6	111.0	109.3	107.6	108.6	103.0	100.0	91.9	103.0
2000	112.3	110.9	109.7	112.4	111.4	110.3	110.1	110.6	108.6	100.6	116.6
2500	105.8	104.7	103.7	106.0	105.1	104.3	103.9	113.6	110.6	103.6	114.6
3150	106.9	106.0	105.1	107.0	106.3	105.6	105.3	113.2	112.7	106.2	114.2
4000	110.2	109.6	108.9	110.3	109.9	109.3	108.9	113.7	113.2	109.7	114.7
5000	110.2	109.8	109.3	110.2	109.9	109.5	109.0	113.2	112.7	109.2	114.2
6300	109.0	108.9	108.7	108.9	108.8	108.6	108.1	115.7	115.2	111.7	116.7
8000	104.7	104.9	105.0	104.6	104.6	104.5	104.1	113.4	112.9	109.4	114.4
10000	105.6	106.0	106.4	105.4	105.5	105.6	105.2	113.0	112.5	109.0	114.0

Wavelength [cm]	Lh,veh,i										
	Cast Iron braked wheel on Dutch typical rail roughness	Disk braked wheel on Dutch typical rail roughness	Disk braked wheel on smooth roughness rail	ISO spectrum TSI			Very smooth wheel on Dutch typical rail roughness	Composite Block on smooth roughness rail	Maximum roughness combined	Minimum roughness combined	Roughness of standard disk braked wheel
	ireff_CI_netrail	ireff_disc_netrail	ireff_disc_smol	ireff_iso	ireff_tsi	ireff_netrail	ireff_KB_smoc	ireff_upperlimit	ireff_lowerlimit	ireff_srmcat8	
63	20	11	20.5	23.5	17.1	11	18.5	25	5	11	
50	17	11	18.7	21.7	17.1	11	16.7	20	0	11	
40	14	11	16.8	19.8	17.1	11	14.8	20	-5	11	
31.5	12	10	15	18	15	10	13	20	-6	10	
25	10	9	13.1	16.1	13	9	11.1	20	-7	9	
20	10	8	11.3	14.3	11	8	9.3	20	-8	8	
16	11	7	9.4	12.4	9	7	7.4	20	-9	7	
12	11	6	7.6	10.6	7	6	5.6	20	-10	6	
10	11	5	5.8	8.8	4.9	5	3.8	20	-11	5	
8	13	3.8	3.7	6.7	2.7	3.8	1.7	20	-12	3.8	
6.3	14	2.5	1.6	4.6	0.4	2.5	-0.4	20	-13	2.5	
5	14	1.1	-0.7	2.3	-2	1.1	-2.7	20	-14	1.1	
4	13	-0.6	-3.2	-0.2	-4.8	-0.6	-5.2	20	-15	-0.6	
3.2	10	-2.5	-6	-3	-7.5	-2.5	-8	19	-16	-2.5	
2.5	7	-4.8	-9.1	-6.1	-9.4	-4.8	-11.1	17	-17	-4.8	
2	3	-7.8	-12.9	-9.9	-12	-7.8	-14.9	15	-20	-7.8	
1.6	-2	-11.5	-17.5	-14.5	-15.3	-11.5	-19.5	10	-23	-16	
1.2	-7	-15.4	-22.2	-19.2	-18.8	-15.4	-24.2	5	-27	-19	
1	-14	-17	-24.7	-21.7	-20	-17	-26.7	0	-30	-22	
0.8	-19.5	-19.5	-26.2	-23.2	-22.1	-19.5	-28.2	-5	-31	-25	
0.63	-21.5	-21.5	-27.2	-24.2	-23.7	-21.5	-29.2	-10	-32	-28	
0.5	-24	-24	-28.7	-25.7	-25.8	-24	-30.7	-15	-33	-31	
0.4	-25.5	-25.5	-29.2	-26.2	-26.9	-25.5	-31.2	-20	-34	-34	
0.32	-27.7	-27.7	-30.4	-27.4	-28.7	-27.7	-32.4	-25	-35	-37	
0.25	-29.6	-29.6	-31.3	-28.3	-30.2	-29.6	-33.3	-26	-36	-40	
0.2	-31.6	-31.6	-32.3	-29.3	-31.8	-31.6	-34.3	-27	-37	-43	
0.16	-33.6	-33.6	-33.3	-30.3	-33.4	-33.6	-35.3	-28	-38	-46	
0.13	-35.6	-35.6	-34.3	-31.3	-35	-35.6	-36.3	-29	-39	-49	
0.1	-37	-37.6	-35.3	-32.3	-36.6	-37.6	-37.3	-30	-40	-52	

Appendix IV-C

$L_{R,IMPACT,i}$ is a third octave band spectrum (as a function of frequency). A default spectrum is given as function of wavelength λ here.

Wavelength [cm]	$L_{rimpact_single,i}(\lambda)$
63	22.4
50	23.8
40	24.7
31.5	24.7
25	23.4
20	21.7
16	20.2
12	20.4
10	20.8
8	20.9
6.3	19.8
5	18
4	16
3.2	13
2.5	10
2	6
1.6	1
1.2	-4
1	-11
0.8	-16.5
0.63	-18.5
0.5	-21
0.4	-22.5
0.32	-24.7
0.25	-26.6
0.2	-28.6
0.16	-30.6
0.13	-32.6

Appendix IV-D

Parameters for default calculation of squeal noise are presented here.

Freq. [Hz]	LW,squeal,0
1000	Only defined at 130 1000 Hz

Appendix IV-E

Parameters for default calculation of braking noise are presented here.

$L_{W,0,ref,bb}(v_0)$, the reference value for broadband braking noise for given speed v_0 , is tabulated here.

Freq [Hz]	LW,0,ref,BB
25	-99
31.5	-99
40	-99
50	-99
63	-99
80	-99
100	-99
125	-99
160	-99
200	-99
250	-99
315	-99
400	-99
500	-99
630	-99
800	117.1
1000	117.0
1250	117.1
1600	117.3
2000	117.2
2500	117.2
3150	117.3
4000	117.1
5000	117.1
6300	117.1
8000	116.9
10000	-99

C_{brake} the speed dependency factor, is tabulated here.

$$C_{brake}=30$$

$L_{W,0,ref,bs}$ the reference value for braking squeal, is tabulated here.

Freq. [Hz]	LW,0,ref,bs
1000	Only defined at 130 1000 Hz

d_{squeal} the duration correction for braking squeal, is tabulated here.

$$D_{\text{squeal}}=0.5$$

Appendix IV-F

The standard proportion of traction noise to be attributed to the two sources heights is given here.

$$L_{W,0,acc,0,5m}=L_{W,0,acc,0,5m}=L_{W,0,acc}-3$$

LW,0,acc,i (Traction)	Traction 1	Traction 2
Frequency	Electric locomotive	Electrically Motored Unit/with gears
25	68	58
31.5	67	60
40	68	57.3
50	69	60
63	75	60
80	69	56.3
100	70	56
125	72	70
160	74	55.3
200	85	55
250	76	70
315	75	54.3
400	80	54
500	73	53.6
630	71	53.33
800	70	53
1000	75	60
1250	67	55
1600	65	57
2000	63	55
2500	61	52
3150	59	49
4000	57	46
5000	55	43
6300	53	40
8000	51	37
10000	49	34

Appendix IV-G

Parameters for default calculation of aerodynamic noise are presented here.

The default suggested values are: $\alpha_2 = \alpha_4 = \alpha_5 = 50$

Appendix IV-H

C_{bridge} is a constant that can be obtained depending on the bridge type from measurements of the difference between over the bridge and not over the bridge comparison of measured data.

CHAPTER V. INDUSTRIAL NOISE SOURCE EMISSION

V.1 Source description

V.1.1. Classification of source types (point, line, area)

The industrial sources are of very variable dimensions, they can be large industrial plants as well as small concentrated sources like small tools or operating machines used in factory. Therefore, it is necessary to use an appropriate modelling technique for the specific source under assessment. Depending on the dimension and the way several single sources extend over an area, though belonging to the same industrial site, these are better modelled as point sources, line source or area source. In practice, the calculations of the noise effect is always based on point sources, but several point sources can be used to represent a real complex source which mainly extends over a line or an area.

V.1.2. Number and position of equivalent sound sources

The sound sources are modelled as one or more equivalent point sources so that the total sound power of the source corresponds to the sum of the single sound powers attributed to the different point sound sources.

The general rule to be applied in defining the number of equivalent point sources to be used is that:

- Line or surface sources whose largest dimension is less than 1/2 of the distance between the source and the receiver can be modelled as single point sources.
- Sources whose largest dimension is more than 1/2 of the distance between the source and the receiver shall be modelled as a series of point sources in a line or as a series of point sources over an area, such that for each of these sources the conditions of 1/2 is fulfilled. The distribution over an area can include vertical distribution of point sources.
- Sources whose largest dimensions in height are over 2 meter or are near the ground, special care should be administered to the height of the source. Doubling the number of sources, redistributing them only in the z-component, may not lead to a relevant other result for this source.
- In the case of any source, doubling the number of sources over the source area (in all dimensions) may not lead to a relevant other result.

The position of the equivalent sound sources cannot be fixed, given the large number of configurations that an industrial site can have. Best practice shall normally apply.

V.2. Sound power emission

V.2.1. General

The following information constitutes the complete set of input data for sound propagation calculations with the methods to be used for noise mapping:

- Emitted sound power level spectrum in 1/1 octave bands
- Working hours (day, evening, night, on a yearly averaged basis)
- Location (coordinates x, y) and elevation (z) of the noise source
- Type of source (point-, line-, area- source)
- Dimensions and orientation
- Operating conditions of the source
- Directivity of the source

It shall be noted that lacking of some of the listed information and replacement by assumed or somehow uncertain information is in many cases not severe for industrial noise assessment because the total error is reduced if many sources contribute simultaneously.

The point, line and area source sound power are required to be defined as:

- For a point source, sound power L_W and directivity as a function of the three orthogonal coordinates (x, y, z);
- Two types of line sources can be defined:
 - line sources representing conveyor belts, pipe lines, etc. , sound power per meter length $L_{W/m}$ and directivity as a function of the two orthogonal coordinates to the axis of the equivalent line source;
 - line sources representing moving vehicles, sound power L_w and directivity as a function of the two orthogonal coordinates to the axis of the equivalent line source and the speed and number of vehicles travelling along this line during day, evening and night;
- For an area source, sound power per squared meter L_{W/m^2} , and no directivity (may be horizontal or vertical).

The working hours are an essential input for the calculation of noise levels. The working hours should be given for the day, evening and night period and, if the propagation is using different meteorological classes defined during each of the day, night and evening period, then a finer distribution of the working hours should be given in sub-periods matching the distribution of meteorological classes. This information shall be based on a yearly average.

The correction for the working hours, to be added to the source sound power to define the corrected sound power to be used for calculations over each time period, C_W in dB, is calculated as follows:

$$C_W = 10 \times \lg \left(\frac{t}{T_0} \right) \quad (V-1)$$

where:

t is the active source time per period based on a yearly averaged situation, in hours;

T_0 is the reference period of time in hours (e.g.: day: 12 hours, evening: 4 hours, night: 8 hours].

For the more dominant sources, the yearly average working hours correction should be estimated at least within 0.5 dB tolerance in order to achieve an acceptable accuracy (this is equivalent to an uncertainty of less than 10% in the definition of the active period of the source).

V.2.2. Source directivity

The source directivity is strongly related to the position of the equivalent sound source next to nearby surfaces. Because the propagation method considers the reflection of the nearby surface as well its sound absorption, it is necessary to consider carefully the location of the nearby surfaces. In general, it shall always be distinguished between the two cases:

- a source sound power and directivity is determined and given relative to a certain real source when this is in free field (excluding also the terrain effect);
- a source sound power and directivity is determined and given relative to a certain real source when this is placed in a specific location and therefore the source sound power and directivity is in fact an “equivalent” one, since it includes the modelling of the effect of the nearby surfaces.

The method can handle both cases, under the following conditions:

- in case the source sound power and directivity is given following the first rule, nearby surfaces should at least be 0.01 m from the equivalent point source;
- in case the source sound power and directivity is given following the second rule, nearby surfaces already included in the definition of the source shall not be included in the propagation calculation for this source.

The directivity shall be expressed in the calculation as a factor $\Delta L_{w,dir,xyz}(x, y, z)$ to be added to the sound power to obtain the right equivalent sound power of a reference sound source seen by the sound propagation in the direction given. The factor can be given as a function of the direction vector defined by (x,y,z) with $\sqrt{x^2 + y^2 + z^2} = 1$. This directivity can be also expressed by means of other coordinate systems like angular coordinate systems.

V.2.3. Measurements

In traffic noise one can assume that the variety of different cars over a whole year can be taken as a standard averaged car with a certain speed. This is not the case for industry, the same sources tends to be there for a very long time, no averaging takes place. Therefore, each relevant source should be measured to get accurate sources and noise maps.

There exists a considerable number of standards and guidelines on measurement methods for industrial noise sources. These standards are meant to be the best practices to use for the

determination of sound power levels and directivity for different source types, from extended sources like industrial sites as a whole, to small appliances and machinery.

The following is a classification of such set of standards to be used.

- Standards that describe general methods for classes of noise sources, special methods for specific single noise sources or methods for whole plants or industries
- Standards that are originally intended to provide data for the assessment of
 - the source sound power level
 - working place noise
 - a comparison of the noise emissions of different sources of a kind
 - noise emissions under specific operating conditions
- Standards that apply to measurements in the field or in special test rooms
- Standards of different grades of accuracy
- Standards that require special measuring equipment

It is logical to rely on these standards also for measurements the objective of which is the determination of source sound power level and directivity to be used with this method. A list of such standards is given in Appendix V-A.

Unfortunately, the methods described in the standards are often not specifically intended to provide input data for noise mapping purposes, so that there may be certain shortcomings in using a specific standard for that purpose even if, in principle, it is applicable to the source(s) in question. On the other hand, in some cases, the described methods can be improved by simple means to yield the desired information even if they were not originally aimed at providing that information.

Accordingly, the end user, searching for an appropriate measurement method for his/her particular sound source to acquire input data for noise mapping, has to choose from these different standards.

V.2.4. Use of pre-defined database

The preferred approach is to perform measurements of the source but, if not possible, a database can be used for determining the source sound power and directivity as well as typical working hours, for each source. A default database is given in Appendix V-B.

Appendix V-A

To the purpose of collecting appropriate sound power spectra to be used in the calculation of industrial noise, it is advised to make use of the following standards:

- **sound pressure enveloping surface method (ISO 3744 and 3746)**
- **reverberation room method (ISO 3741)**
- **reference sound source method (ISO 3747)**
- **intensity method (ISO 9614 1 – 3)**
- **multi source industrial plants (ISO 8297)**
- **transmission in the outdoor (EN 12354-4)**

Appendix V-B

To the purpose of finding default values for industrial noise the following database is available (to be added at a later stage by CNOSSOS-EU WG/DT7).

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CHAPTER VI. SOUND PROPAGATION

VI.1. Scope and applicability of the method

The sound propagation model described in this chapter and the text contained is extracted or based on the formulations developed within the NF-S 31-133 standard.

This document specifies a method of calculation of the attenuation of noise during its outdoor propagation. Knowing the characteristics of the source, this method helps to determine the equivalent continuous sound pressure level at a receiver point corresponding to two particular types of atmospheric conditions:

- downward-refraction propagation conditions (positive vertical gradient of effective sound celerity) from the source to the receiver;
- homogeneous atmospheric conditions (null vertical gradient of effective sound celerity) over the entire area of propagation.

The method of calculation described in this document applies to industrial infrastructures and land transport infrastructures. It therefore applies in particular to road and railway infrastructures. Aircraft transport is included in the scope of the method only for the noise produced during at ground operations and excluded take off and landing.

Industrial infrastructures that emit impulsive or strong tonal noises do not fall within the scope of this method.

The method of calculation does not provide results in upward-refraction propagation conditions (negative vertical gradient of effective sound celerity).

To calculate the attenuation due to atmospheric absorption in the case of a transport infrastructure, the temperature and humidity conditions are defined in a conventional way.

The method provides results per frequency band, from 100 Hz to 5 000 Hz. The calculations are made for each of the centre frequencies.

The method is based on a breakdown of the infrastructures into point sources.

The limit of validity of the calculations in distance is 800 m for a normal distance to the road. Only the receiver points located 2 m high at least in relation to the ground may be taken into account.

The method of calculation does not apply to propagation scenarios above a water body (lake, wide river, etc.).

The method of calculation applies to any type of environment: rural environment, urban environment, including “U-shaped” streets.

Partial covers and obstacles sloping more than 15° in relation to the vertical are only dealt with by this method when it is applied in three dimensions.

The effects of tunnel mouths are not dealt with by the method proposed in this document.

This method considers obstacles to be equivalent to flat surfaces. Successive diffraction calculations are not dealt with by this document. They are treated as multiple diffractions.

The application of this document assumes detailed knowledge of:

- the topography of the sites;
- the geometry of the source and obstacles;
- the acoustic characteristics of the obstacles;
- the nature of the ground;
- the sound power of the sources;
- the occurrences of meteorological downward-refraction conditions in all the or each propagation directions concerned.

VI.2. Set up of the model

VI.2.1. Definitions used

All distances, heights, dimensions and altitudes used in this document are expressed in metres (m).

The notation MN stands for the distance between the points M and N, measured according to a straight line joining these points.

The notation M'N stands for the curved path length between the points M and N, in favourable conditions.

It is customary for real heights measured vertically in relation to the ground to be noted with the letter h; equivalent heights measured orthogonally in relation to the mean ground plane are noted with the letter z.

The sound levels, noted with the capital letter L, are expressed in decibels (dB) per frequency band when index A is omitted. The sound levels in decibels dB(A) are given the index A.

The sum of the sound levels due to mutually incoherent sources is noted by the sign \oplus in accordance with the following definition:

$$L_1 \oplus L_2 = 10 \cdot \lg \left[10^{L_1/10} + 10^{L_2/10} \right] \quad (\text{VI-1})$$

VI.2.2. Geometrical considerations

This section presents only the basic concepts of the geometrical model. More details will be provided in the Guidance for the competent use of CNOSSOS-EU and will be based on the solutions developed by the CNOSSOS-EU WG 8.

VI.2.2.a. Source segmentation

Real sources are described by a set of point source or, in the case of a railway traffic or road traffic, by incoherent line sources. A line source is divided into line segments, which are represented by point sources located at their centre.

Different techniques exist for the source segmentation. These will be discussed in the Guidance for the competent use of CNOSSOS-EU and will be based on the solutions developed by the CNOSSOS-EU WG 8.

Computational time can be reduced by reducing the number of point sources: this can be achieved by using longer segments, and, in the case of road traffic, a reduced number of lanes.

VI.2.2.b. Propagation paths

As mentioned in section I.3.1, CNOSSOS-EU operates on a geometrical model consisting of a set of connected ground and obstacles surfaces. A propagation path is a vertical plane through the receiver and a point source.

Different techniques exist for finding the paths. These will be discussed in the Guidance for the competent use of CNOSSOS-EU and be based on the solutions developed by the CNOSSOS-EU WG8.

VI.2.2.c. Calculation of the mean plane

In the plane of the path, the topography may be described by a set of discrete points (x_k, z_k) ; $k \in \{1, \dots, n\}$

The determination of the mean plane by linear regression according to the least squares means that the (x_k, z_k) are linearly spaced. In the opposite case, the mean plane shall in general be erroneous.

The recommended spacing is 1 m in abscissa between (x_k, z_k) and (x_{k+1}, z_{k+1}) . Choosing a wider spacing should be justified.

It is assumed that the x increase from the source to the receiver. When the available set of points is not regularly spaced, a new set of points shall be carried out as follows:

$$\begin{cases} x' = \frac{x_{k+1} - x_j}{\sqrt{(x_{k+1} - x_k)^2 + (z_{k+1} - z_k)^2}} (j-1)s + x_k \\ z' = \frac{z_{k+1} - z_j}{\sqrt{(x_{k+1} - x_k)^2 + (z_{k+1} - z_k)^2}} (j-1)s + z_k \end{cases} \quad (VI-2)$$

where s is the step, in metres.

A main characteristic of the set of points produced by formula VI-2 is that it contains the original scatter points. Since, in general, a perfectly regular set of points cannot be created with a set of points that is not regular, the set of points produced by formula VI-2 coincides “to the left” with the original scatter.

An irregularly spaced set of points may also be considered as defining a polyline of straight segments $z_k = a_k x + b_k$, $x \in [x_k, x_{k+1}]$; $k \in \{1, \dots, n\}$, and therefore the straight line $z = ax + b$; $x \in [x_1, x_n]$, which is adjusted to the polyline, can be analytically expressed, according to the least squares.

The following is written

$$\begin{cases} A = \frac{2}{3} \sum_{k=1}^{n-1} a_i (x_{k+1}^3 - x_k^3) + \sum_{k=1}^{n-1} b_i (x_{k+1}^2 - x_k^2) \\ B = \sum_{k=1}^{n-1} a_i (x_{k+1}^2 - x_k^2) + 2 \sum_{k=1}^{n-1} b_i (x_{k+1} - x_k) \end{cases} \quad (VI-3)$$

With these notations, the straight line sought has the following coefficients:

$$\begin{cases} a = \frac{3(2A - B(x_n + x_1))}{(x_n - x_1)^3} \\ b = \frac{2(x_n^3 - x_1^3)}{(x_n - x_1)^4} B - \frac{3(x_n - x_1)}{(x_n - x_1)^3} A \end{cases} \quad (VI-4)$$

VI.2.2.d. Reflections by building façades and other vertical obstacles

Contributions from reflections are taken into account e.g. by the introduction of image sources or image receivers.

Different techniques exist for the calculation of reflections. These will be discussed in the Guidance for the competent use of CNOSSOS-EU and be based on the solutions developed by the CNOSSOS-EU WG8.

VI.2.3. Sound propagation model

VI.2.3.a. Calculation approach

For a receiver R the calculations are made according to the following steps:

- 1) breakdown of the noise sources into point sources, if not already expressed as point sources;
- 2) determination of the sound power level of each source;
- 3) calculation of the probability of occurrence of favourable conditions for each direction source S_i to receiver R (S_i, R);
- 4) search for propagation paths between each source and receiver: direct, reflected and/or diffracted paths;
- 5) on each propagation path:
 - calculation of the attenuation in favourable conditions;
 - calculation of the attenuation in homogeneous conditions;
 - calculation of the occurrence of favourable conditions;
 - calculation of the long-term sound level for each path;
- 6) accumulation of the long-term sound levels for each path, therefore allowing the total sound level to be calculated at the receiver point.

It should be noted that only the attenuations due to the ground effect (A_{ground}) and diffraction (A_{dif}) are affected by the meteorological conditions.

VI.2.3.b. Calculation process

For a sound point source S of power L_{Awi} and for a given frequency band, the equivalent continuous sound pressure level at a receiver point R in given atmospheric conditions shall be obtained according to the following formulae:

VI.2.3.c. Sound level in favourable conditions (L_F) for a path (S,R)

$$L_F = L_{W,0,dir} - A_F \quad (\text{VI-5})$$

The term A_F represents the total attenuation along the propagation path in favourable conditions, and is broken down as follows:

$$A_F = A_{\text{div}} + A_{\text{atm}} + A_{\text{boundary},F} \quad (\text{VI-6})$$

where

A_{div} is the attenuation due to geometrical divergence;

A_{atm} is the attenuation due to atmospheric absorption;

$A_{\text{boundary,F}}$ is the attenuation due to the boundary of the propagation medium in favourable conditions. It may contain the following terms:

$A_{\text{ground,F}}$ which is the attenuation due the ground in favourable conditions;

$A_{\text{dif,F}}$ which is the attenuation due to diffraction in favourable conditions;

For a given path and frequency band, the following two scenarios are possible:

- either $A_{\text{ground,F}}$ ($A_{\text{dif,F}} = 0$ dB) are calculated, with no diffraction and $A_{\text{boundary,F}} = A_{\text{ground,F}}$;
- or $A_{\text{dif,F}}$ ($A_{\text{ground,F}} = 0$ dB) is calculated. The ground effect is taken into account in the $A_{\text{dif,F}}$ formula itself. This therefore gives $A_{\text{boundary,F}} = A_{\text{dif,F}}$.

VI.2.3.d. Sound level in homogeneous conditions (L_H) for a path (S,R)

The procedure is strictly identical to the case of favourable conditions presented in the previous subclause.

$$L_H = L_{W,0,dir} - A_H \quad (\text{VI-7})$$

The term A_H represents the total attenuation along the propagation path in homogeneous conditions, and is broken down as follows:

$$A_H = A_{\text{div}} + A_{\text{atm}} + A_{\text{boundary,H}} \quad (\text{VI-8})$$

where

A_{div} is the attenuation due to geometrical divergence;

A_{atm} is the attenuation due to atmospheric absorption;

$A_{\text{boundary,H}}$ is the attenuation due to the boundary of the propagation medium in homogeneous conditions. It may contain the following terms:

$A_{\text{ground,H}}$ which is the attenuation due to the ground in homogeneous conditions;

$A_{\text{dif,H}}$ which is the attenuation due to diffraction in homogeneous conditions;

For a given path and one-third-octave, the following two scenarios are possible:

- either $A_{\text{ground,H}}$ ($A_{\text{dif,H}} = 0$ dB) are calculated, with no diffraction and $A_{\text{boundary,H}} = A_{\text{ground,H}}$;
- or $A_{\text{dif,H}}$ ($A_{\text{ground,H}} = 0$ dB) is calculated. The ground effect is taken into account in the $A_{\text{dif,H}}$ formula itself. This therefore gives $A_{\text{boundary,H}} = A_{\text{dif,H}}$

VI.2.3.e. Long term sound level for a path (S,R)

The “long-term” sound level along a path starting from a given point source is obtained by energy summing the sound level in homogeneous conditions L_H and the sound level in favourable conditions L_F .

These sound levels are weighted by the mean occurrence p of favourable conditions in the direction of the path (S,R):

$$L_{LT} = 10 \lg \left(p \cdot 10^{\frac{L_F}{10}} + (1 - p) \cdot 10^{\frac{L_H}{10}} \right) \quad (\text{VI-9})$$

NOTE Concerning the p factor: the occurrence values to be produced in the tables in the Guidance for competent use of CNOSSOS-EU are expressed in percentages; if for example, the occurrence value is 82 %, the following should be taken in formula VI-9: $p = 0,82$.

VI.2.3.f. Long term sound level R for all paths

The total long-term sound level at the receiver for a one frequency band is obtained by energy summing contributions from all N paths, all types included:

$$L_{tot,LT} = 10 \cdot \lg \left(\sum_n 10^{\frac{L_{n,LT}}{10}} \right) \quad (\text{VI-10})$$

where

n is the index of the paths between S and R.

Taking reflections into account by means of image-sources is described in VI.4.5. The percentage of occurrences of favourable conditions in the case of a path reflected on a vertical obstacle shall be taken as identical to the occurrence of the direct path:

If S' is the image source of S , then the occurrence p' of the path (S',R) is taken as equal to the occurrence p of the path (S_i,R).

VI.2.3.g. Long-term sound level at point R in decibels A (dBA)

The total sound level in decibels A (dBA) is obtained by summing levels in each frequency band:

$$L_{A,eq,LT} = 10 \cdot \lg \sum_i 10^{\frac{(L_{tot,LT,i} + AWC_{f,i})}{10}} \quad (\text{VI-11})$$

where i is the index of the frequency band

This level $L_{A,eq,LT}$ constitutes the final result, i.e. the long-term A-weighted sound pressure level at the receiver point on a specific reference time interval (e.g.: day or evening, or night or a shorter time during day, evening or night when constant source conditions are found).

VI.3 Propagation analysis

VI.3.1. Receiver

The receiver points shall not be placed less than 2 m above the ground. This height shall be known to the nearest 0,10 m at least to limit the uncertainty on the results, in particular if diffraction is present.

By default, the method calculates the sound levels without taking the last reflection from a building façade into account for receiver close to a façade.

To meet the application requirements of the regulations in force in terms of noise thresholds, generally the receivers shall be placed 2 m in front of building façades. The façade effect can, if required to be taken into account, then be approximated:

- either by adding a pre-defined correction of + 3 dB(A) to the $L_{A,eq,LT}$ calculated;
- either by adding a more precise correction as a function of the frequency and site characteristics;
- or by calculating the reflection, according to the method described in VI.4.5.

VI.3.2. Elementary propagation paths

In general, four types of paths can be considered which are described in the following subclauses.

VI.3.2.a. Type 1 paths

These are “direct” paths from the source to the receiver, which are straight paths in plane view, and which may nevertheless include diffractions on the horizontal edges of obstacles (see Figure VI.1). These are the easiest scenarios to deal with.

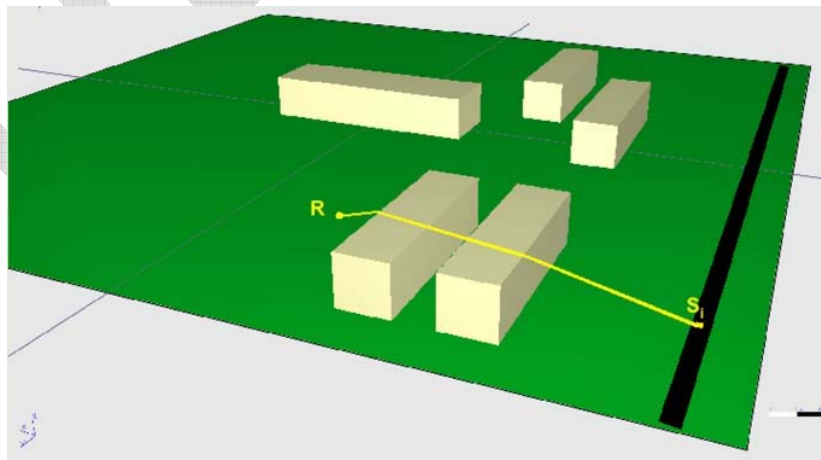


Figure VI.1 — Type 1 path

The 2D section of the geometry is created in a vertical plane passing through the identified path.

VI.3.2.b. Type 2 paths

These are paths reflected on vertical or slightly sloping ($< 15^\circ$) obstacles, as shown in Figure VI.2, which may also include diffractions on the horizontal edges of obstacles (see Figure VI.3).

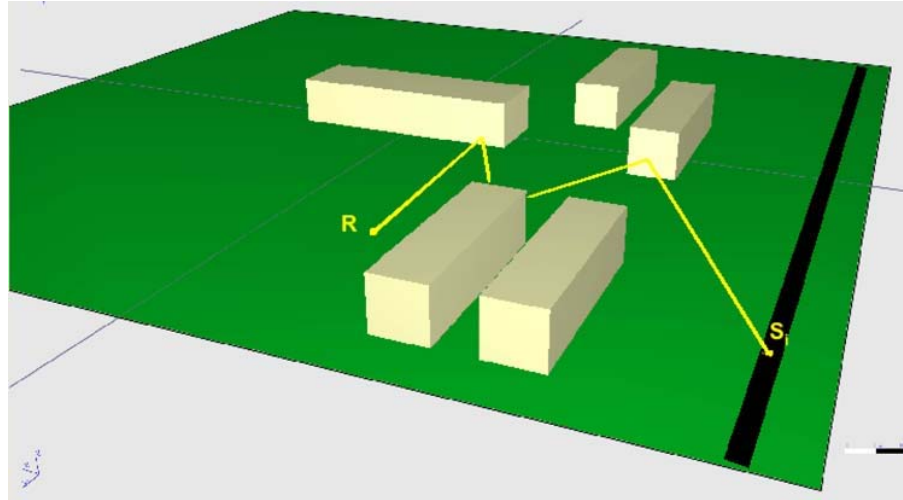


Figure VI.2 — Type 2 path

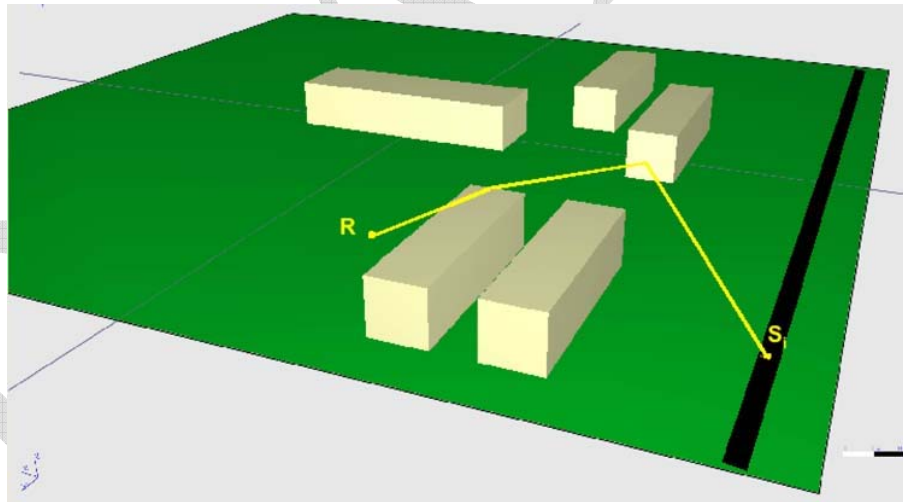


Figure VI.3 — Type 2 path with diffraction on horizontal edge

The principle is to apply the image method. A 2D section of the geometry is created in a succession of vertical planes passing through the straight segments located between two reflections. The section is obtained by unfolding these planes that resemble a Japanese screen and the reflections are taken into account by allocating the sound power of a term which takes the reflection coefficient of each vertical surface encountered into account. If the order equals 1, the power L'_w to be considered is obtained in accordance with formula VI-37. If the order equals 2, the power L''_w to be considered is obtained by applying formula VI-37 where L_w is replaced by L'_w and L'_w by L''_w . This continues until the required order n is reached. The calculation is then made in the 2D vertical section in accordance with the indications in VI.4.5.

VI.3.2.c. Type 3 paths

These are the paths diffracted by the lateral edges of obstacles (see Figure VI.4).

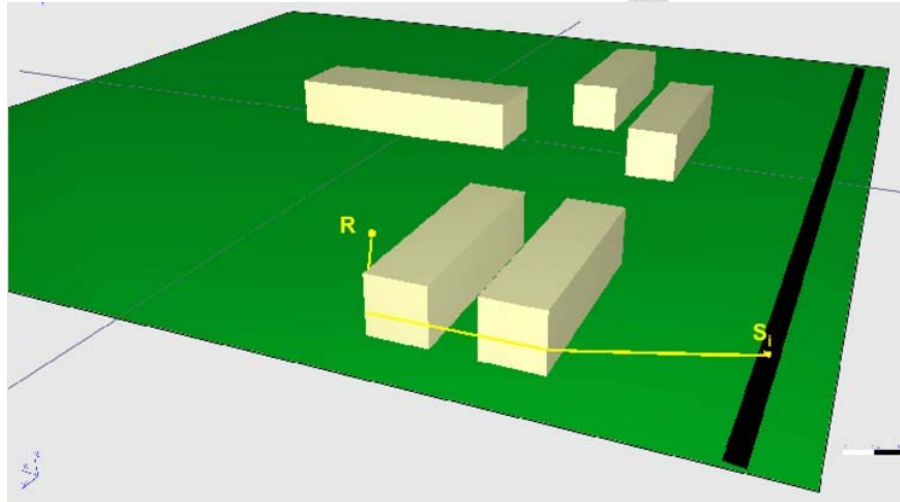


Figure VI.4 — Type 3 path

The principle is to determine each term of formula 41 in homogeneous conditions and formula 42 in favourable conditions:

- the term $\Delta_{\text{dif}}(S,R)$ is obtained by calculating the path difference δ between the direct path and the convex-hull path of lateral edges in the horizontal plane;
- the term A_{ground} is determined without taking the presence of the shield into account.

VI.3.2.d. Type 4 paths

These are mixed paths which are diffracted by the lateral edges of obstacles and reflected by vertical surfaces ($< 15^\circ$). The calculation is therefore the same as for type 3 paths with a simple correction of the source power as for type 2 paths.

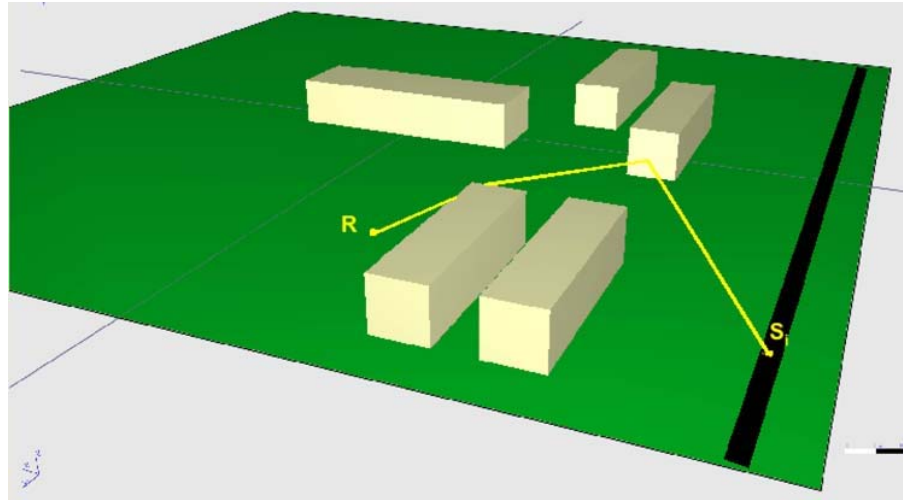


Figure VI.5 — Type 4 paths

VI.4. Calculations on an elementary path

This clause applies when the Euclidean distance between the source and the receiver does not exceed 2000 m. The other paths shall be ignored.

VI.4.1. Geometrical divergence

The attenuation due to geometrical divergence, A_{div} , corresponds to reduction of the sound level due the propagation distance. For a point sound source in free field, the attenuation in decibels is given by:

$$A_{div} = 20\lg(d) + 11 \quad (\text{VI-12})$$

where d is the direct distance between the source and the receiver.

VI.4.2. Atmospheric absorption

The attenuation due to atmospheric absorption A_{atm} during propagation over a distance d is given in decibels by the formula:

$$A_{atm} = \alpha_{atm} d / 1000 \quad (\text{VI-13})$$

where

d is the direct distance between the source and the receiver, in metres;

α_{atm} is the atmospheric attenuation coefficient in decibels per kilometre at the nominal centre frequency for each frequency band, in accordance with ISO 9613-1. The values of the α_{atm} coefficient are given for a temperature of 15 °C, a relative humidity of 70 % and an atmospheric pressure of 101 325 Pa. They are calculated with the exact centre frequencies of the frequency band. These values comply with ISO 9613-1. Using other temperature and humidity values is allowed provided that these represent a meteorological average over the long term.

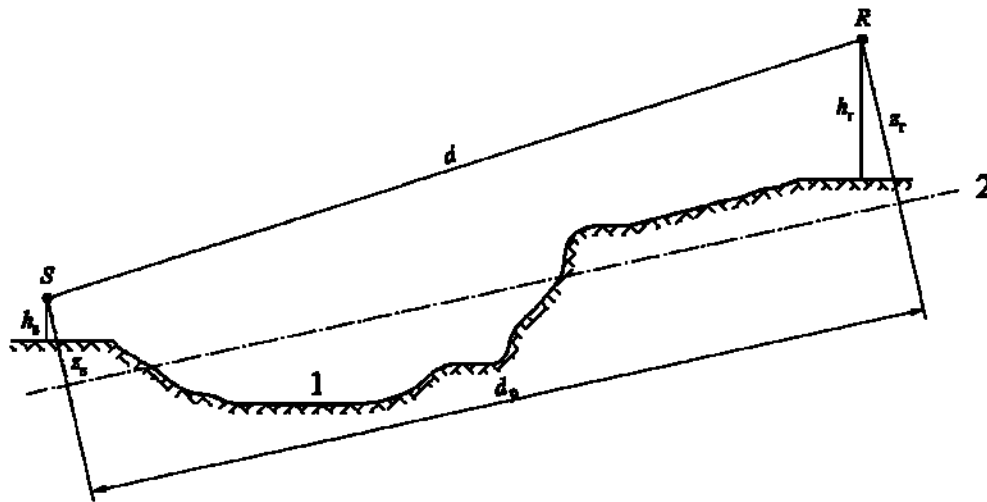
VI.4.3. Ground effect

The attenuation due to the ground effect is mainly the result of the interference between the reflected sound and the sound which is propagated directly from the source to the receiver. It is physically linked to the acoustic absorption of the ground above which the sound wave is propagated. But, it is also significantly dependent on atmospheric conditions during propagation, as ray bending modifies the height of the path above the ground and makes the ground effects and land located near the source more or less significant.

VI.4.3.a. Significant heights above the ground

To take into account the actual relief of the land along a propagation path in the best possible way, the notion of “equivalent height” is introduced which substitutes the real heights in the ground effect formulae.

In this document, it is customary for real heights above the ground to be noted h and equivalent heights to be noted z . The equivalent heights are obtained from the mean ground plane between the source and the receiver. This replaces the actual ground with a fictitious plane representing the mean profile of the land (see Figure VI.6). Instructions on the method for calculating the mean plane are given in VI-2-1.



1: Actual relief

2: Mean plane

Figure VI-6 — Equivalent heights in relation to the ground

The equivalent height of a point is its orthogonal height in relation to this mean plane. The equivalent height z_s and the equivalent receiver height z_r can therefore be defined. The distance between the source and receiver in projection over the mean plane is noted d_p .

If the equivalent height of a point becomes negative, i.e. if the point is located above the mean ground plane, a null height is retained, and the equivalent point is then identical with its possible image if there is diffraction.

VI.4.3.b. Acoustic characterisation of ground

The acoustic absorption properties of ground are mainly linked to its porosity. Compact ground is generally reflective and porous ground is absorbent.

For operational calculation requirements, the acoustic absorption of a ground is represented by a dimensionless G coefficient, between 0 and 1. G is independent of the frequency. Table VI.1 gives the G value for grounds in the outdoors. In general, the average of the G coefficient over a path takes intermediate values between 0 and 1. Here the mean G represents the absorbent fraction along the path. For an example, see Figure VI-7.

Table VI.1 — G values for different types of ground

Description	Type	(kPa·s/m ²)	G value
Very soft (snow or moss-like)	A	12,5	1
Soft forest floor (short, dense heather-like or thick moss)	B	31,5	1
Uncompacted, loose ground (turf, grass, loose soil)	C	80	1
Normal uncompacted ground (forest floors, pasture field)	D	200	1
Compacted field and gravel (compacted lawns, park area)	E	500	0,7
Compacted dense ground (gravel road, parking lot, ISO 10844)	F	2000	0,3
Hard surfaces (most normal asphalt, concrete)	G	20000	0
Very hard and dense surfaces (dense asphalt, concrete, water)	H	200000	0

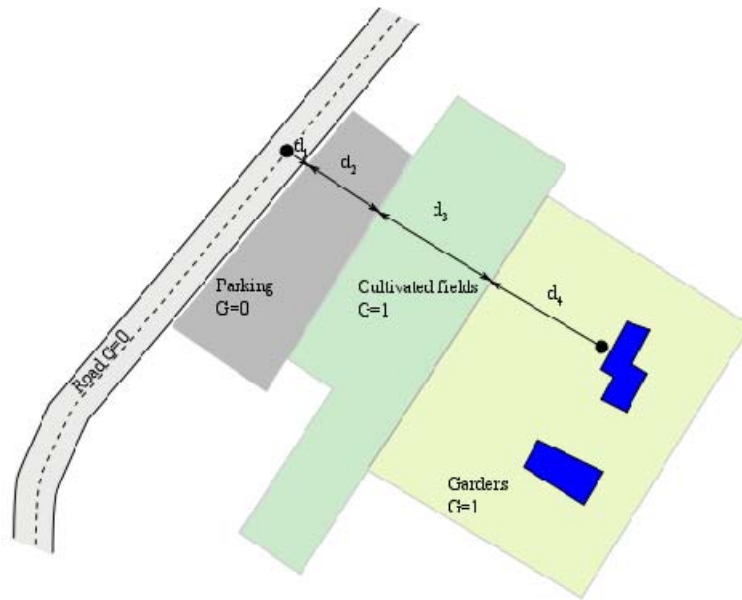
G_{path} is defined as the fraction of absorbent ground present over the entire path covered.

When the source and receiver are close $d_p \leq 30(z_s + z_r)$, the distinction between the type of ground located near the source and the ground located near the receiver no longer means anything. If the receiver is very close to the edge of the platform, an absorbent ground receiver side should not be considered. To take this comment into account, the ground factor G_{path} is therefore ultimately corrected as follows:

$$G'_{path} = \begin{cases} G_{path} \frac{d_p}{30(z_s + z_r)} + G_s \left(1 - \frac{d_p}{30(z_s + z_r)} \right) & \text{if } d_p \leq 30(z_s + z_r) \\ G_{path} & \text{otherwise} \end{cases} \quad \text{(VI-14)}$$

Where G_s is the ground factor of the source area. $G_s=0$ for road platforms¹¹, slab tracks. $G_s=1$ for rail tracks on ballast. There is no general answer in the case of industrial sources and plants.

G may be linked to the flow resistivity.



$$d = d_1 + d_2 + d_3 + d_4$$

$$G_{path} = \frac{(0 \cdot d_1 + 0 \cdot d_2 + 1 \cdot d_3 + 1 \cdot d_4)}{d} = \frac{(d_3 + d_4)}{d}$$

Figure VI.7 — Determination of the ground coefficient G_{path} over a propagation path

Paragraphs VI.4.3.c and VI.4.3.d introduce the generic \bar{G}_w and \bar{G}_m notations for the absorption of the ground. Table V.2 gives the correspondence between these notations and the G_{path} and G'_{path} variables.

Table VI.2 — Correspondence between \bar{G}_w and \bar{G}_m and (G_{path} , G'_{path})

	Homogeneous conditions			Favourable conditions		
	A_{ground}	$\Delta_{ground(S,O)}$	$\Delta_{ground(O,R)}$	A_{ground}	$\Delta_{ground(S,O)}$	$\Delta_{ground(O,R)}$
\bar{G}_w	G'_{path}		G_{path}			
\bar{G}_m	G'_{path}		G_{path}	G'_{path}		G_{path}

11 The absorption of porous road pavements is taken into account in the emission model.

VI.4.3.c. Calculations in homogeneous conditions

The attenuation due to the ground effect in homogeneous conditions is calculated according to the following formulae:

if $G_{\text{path}} \neq 0$

$$A_{\text{ground,H}} = \max \left(-10 \lg \left[4 \frac{k^2}{d_p^2} \left(z_s^2 - \sqrt{\frac{2C_f}{k}} z_s + \frac{C_f}{k} \right) \left(z_r^2 - \sqrt{\frac{2C_f}{k}} z_r + \frac{C_f}{k} \right) \right], A_{\text{ground,H,min}} \right) \quad (\text{VI-15})$$

where

$$k = \frac{2\pi f_m}{c},$$

f_m is the nominal centre frequency of the frequency band considered, in Hertz, c is the celerity of the sound in the air, taken as equal to 340 m/s, and C_f is defined by:

$$C_f = d_p \frac{1 + 3wd_p e^{-\sqrt{wd_p}}}{1 + wd_p} \quad (\text{VI-16})$$

where the values of w are given by the formula below:

$$w = 0,0185 \frac{f_m^{2,5} \overline{G}_w^{-2,6}}{f_m^{1,5} \overline{G}_w^{-2,6} + 1,3 \cdot 10^3 f_m^{0,75} \overline{G}_w^{-1,3} + 1,16 \cdot 10^6} \quad (\text{VI-17})$$

G_w may be equal to either G_{path} or G'_{path} depending on whether the ground effect is calculated with or without diffraction, and according to the nature of the source point. This is specified in the following subclauses.

$$A_{\text{ground,H,min}} = -3(1 - \overline{G}_m) \quad (\text{VI-18})$$

is the lower bound of $A_{\text{ground,H}}$.

For a path (S_i, R) in homogeneous conditions without diffraction:

$$\overline{G}_w = G'_{\text{path}}$$

$$\overline{G}_m = G'_{\text{path}}$$

With diffraction, refer to VI.4.4 for the definitions for \overline{G}_w and \overline{G}_m .

if $G_{\text{path}} = 0$: $A_{\text{ground,H}} = -3\text{dB}$

The term $-3(1 - \overline{G}_m)$ takes into account the fact that when the source and the receiver are far apart, the first reflection source side is no longer on the platform but on the natural land.

VI.4.3.d Calculation in favourable conditions

The ground effect in favourable conditions is calculated with the formula of $A_{\text{ground,H}}$, providing that the following modifications are made:

If $G_{\text{path}} \neq 0$

a) In the formula of $A_{\text{ground,H}}$, the heights z_s and z_r are replaced by $z_s + \delta z_s + \delta z_T$ and $z_r + \delta z_r + \delta z_T$ respectively where

$$\begin{cases} \delta_{z_s} = a_0 \left(\frac{z_s}{z_s + z_r} \right)^2 \frac{d_p^2}{2} \\ \delta_{z_r} = a_0 \left(\frac{z_r}{z_s + z_r} \right)^2 \frac{d_p^2}{2} \end{cases} \quad (\text{VI-19})$$

$a_0 = 2 \times 10^{-4} \text{ m}^{-1}$ is the reverse of the radius of curvature

$$\delta_{z_t} = 6 \cdot 10^{-3} \frac{d_p}{z_s + z_r}$$

b) The lower bound of $A_{\text{ground,F}}$ depends on the geometry of the path:

$$A_{\text{ground,F,min}} = \begin{cases} -3(1 - \overline{G}_m) & \text{if } d_p \leq 30(z_s + z_r) \\ -3(1 - \overline{G}_m) \left(1 + 2 \left(1 - \frac{30(z_s + z_r)}{d_p} \right) \right) & \text{otherwise} \end{cases} \quad (\text{VI-20})$$

If $G_{\text{path}} = 0$

$$A_{\text{ground,F}} = A_{\text{ground,F,min}}$$

The height corrections δ_{z_s} and δ_{z_r} convey the effect of the sound ray bending. δ_{z_t} accounts for the effect of the turbulence.

\overline{G}_m may also be equal to either G_{path} or G'_{path} depending on whether the ground effect is calculated with or without diffraction, and according to the nature of source point. This is specified in the following subclauses.

For a path (S_i, R) in favourable conditions without diffraction:

$$\overline{G}_w = G'_{\text{path}} \text{ in equation VI-17;}$$

$$\overline{G}_m = G'_{\text{path}}.$$

With diffraction, refer to VI.4.4 for the definitions for \overline{G}_w and \overline{G}_m .

VI.4.4. Diffraction

As a general rule, the diffraction shall be studied at the top of each obstacle located on the propagation path. If the path passes “high enough” over the diffraction edge, $A_{\text{dif}} = 0$ can be set and a direct view calculated, in particular by evaluating A_{ground} (VI.4.3).

In practice, for each frequency band centre frequency, the path difference δ is compared with the quantity $-\lambda / 20$. If the path difference λ is less than $-\lambda / 20$, there is no need to calculate A_{dif} for the frequency band considered. In other words, $A_{\text{dif}} = 0$ in this case. Otherwise, A_{dif} is calculated as described in the remainder of this part. This rule applies in both homogeneous and favourable conditions, for both single and multiple diffraction.

When, for a given frequency band, a calculation is made according to the procedure described in this clause, A_{ground} is set as equal to 0 dB when calculating the total attenuation. The ground effect is taken into account directly in the general diffraction calculation formula.

The formulae proposed here are used to process the diffraction on thin screens, thick screens, buildings, earth berms (natural or artificial), and by the edges of embankments, cuttings and viaducts.

When several diffracting obstacles are encountered on a propagation path, they are treated as a single multiple diffraction by applying the procedure described in VI.4.3.

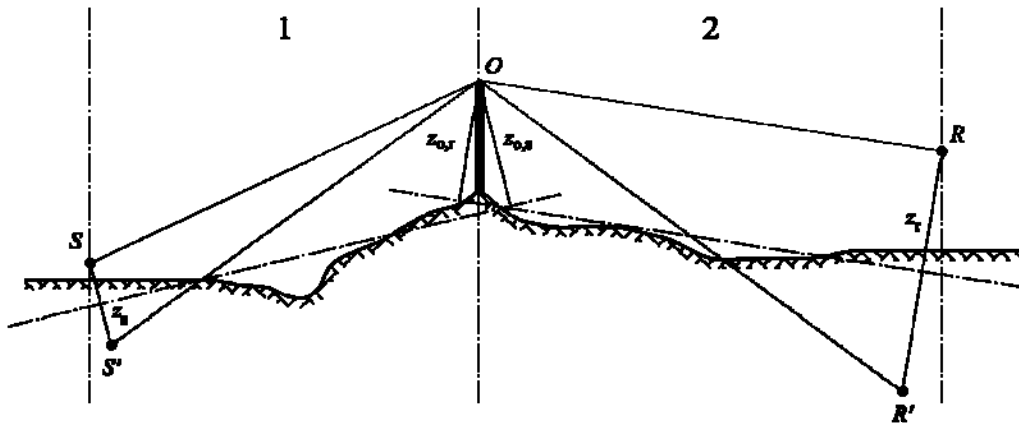
The procedures presented here are used to calculate the attenuations in both homogeneous conditions and favourable conditions. Ray bending is taken into account in the calculation of the path difference and to calculate the ground effects before and after diffraction.

VI.4.4.a. General principles

Figure VI-9 illustrates the general method of calculation of the attenuation due to diffraction. This method is based on breaking down the propagation path into two parts: the “source side” path, located between the source and the diffraction point, and the “receiver side” path, located between the diffraction point and the receiver.

The following are calculated:

- a ground effect, source side, $\Delta_{\text{ground}}(S,O)$
- a ground effect, receiver side, $\Delta_{\text{ground}}(O,R)$;
- and three diffractions:
 - between the source S and the receiver R : $\Delta_{\text{dif}}(S,R)$;
 - between the image source S' and R : $\Delta_{\text{dif}}(S',R)$;
 - between S and the image receiver R' : $\Delta_{\text{dif}}(S,R')$.



1:Source side
2:Receiver side

Figure VI-8— Geometry of a calculation of the attenuation due to diffraction

Where:

S : Source;

R : Receiver;

S' : Image source in relation to the mean ground plane source side;

R' : Image receiver in relation to the mean ground plane receiver side;

O : Diffraction point;

z_s : Equivalent height of the source S in relation to the mean plane source side;

$z_{o,s}$: Equivalent height of the diffraction point O in relation to the mean ground plane source side;

z_r : Equivalent height of the receiver R in relation to the mean plane receiver side;

$z_{o,r}$: Equivalent height of the diffraction point O in relation to the mean ground plane receiver side.

The irregularity of the ground between the source and the diffraction point, and between the diffraction point and the receiver, is taken into account by means of equivalent heights calculated in relation to the mean ground plane, source side firstly, and receiver side secondly (two mean ground planes), according to the method described in VI.4.3.a.

VI.4.4.b. Pure diffraction

For pure diffraction, with no ground effect, the attenuation is given by:

$$A_{diff} = \begin{cases} 10C_h \log_{10} \left(3 + \frac{40}{\lambda} C'' \delta \right) & \text{if } \frac{40}{\lambda} C'' \delta \geq -2 \\ 0 & \text{otherwise} \end{cases} \quad (\text{VI-21})$$

where

$$C_n = \min\left(\frac{f_m h_0}{250}, 1\right) \quad (\text{VI-22})$$

where

f_m is the nominal centre frequency of a frequency band;

h_0 is the greatest of two heights of the diffraction edge in relation to each of the two mean ground planes source side and receiver side;

λ is the wavelength at the nominal centre frequency of the frequency band considered;

δ is the path difference between the diffracted path and the direct path (see V.4.4.c);

C'' is a coefficient used to take into account multiple diffractions:

$C'' = 1$ for a single diffraction;

For a multiple diffraction, if e is the total distance between the diffraction closest to the source and the diffraction closest to the receiver (see Figures V.10 and V.11) and if e exceeds 0,3 m – otherwise $C'' = 1$ -, this coefficient is defined by:

$$C''' = \frac{1 + \left(\frac{5\lambda}{e}\right)^2}{\frac{1}{3} + \left(\frac{5\lambda}{e}\right)^2} \quad (\text{VI-23})$$

The values of Δ_{dif} shall be bound:

- if $\Delta_{\text{dif}} < 0$: $\Delta_{\text{dif}} = 0$ dB;
- if $\Delta_{\text{dif}} > 25$: $\Delta_{\text{dif}} = 25$ dB for a diffraction on a horizontal edge and only on the term Δ_{dif} which figures in the calculation of A_{dif} . This upper bound shall not be applied in the Δ_{dif} terms that intervene in the calculation of Δ_{ground} , or for a diffraction on a vertical edge (lateral diffraction).

VI.4.4.c. Calculation of the path difference

The path difference δ is calculated in a vertical plane containing the source and the receiver. This is an approximation in relation to the Fermat principle. The approximation remains applicable here (source lines). The path difference δ is calculated as in Figures VI.9 and VI.10, based on the situations encountered:

VI.4.4.c.1. Homogeneous conditions

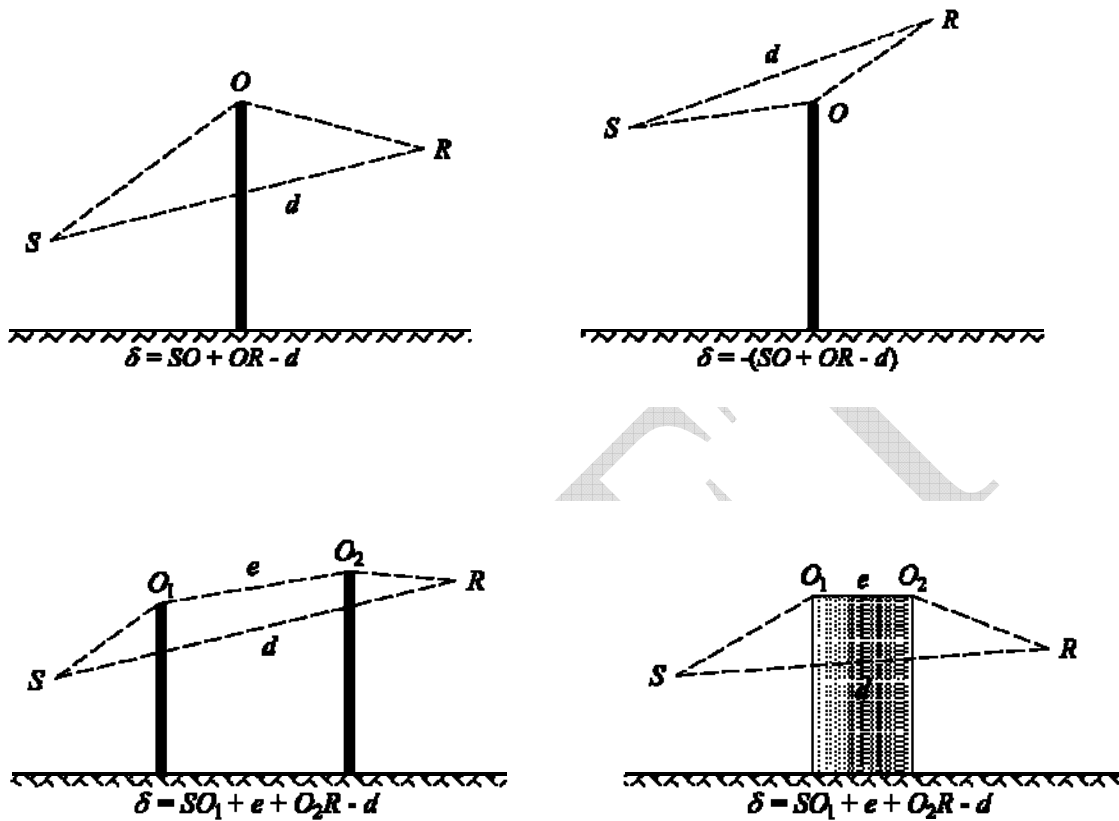


Figure VI.9— Calculation of the path difference in homogeneous conditions. O , O_1 and O_2 are the diffraction points

NOTE For each configuration, the expression of δ is given.

VI.4.4.c.2. Favourable conditions

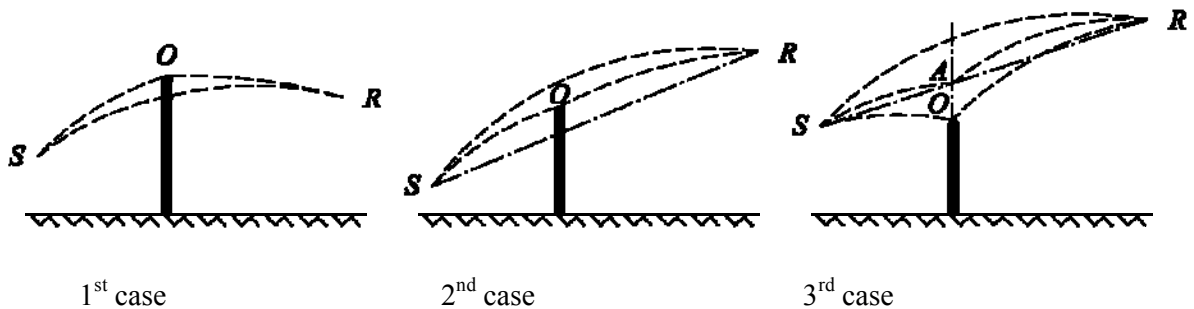


Figure VI.10 — Calculation of the path difference in favourable conditions (single diffraction)

The length of a sound ray curve MN is noted \hat{MN} in favourable conditions. This length is equal to:

$$\hat{MN} = 2\Gamma \arcsin\left(\frac{MN}{2\Gamma}\right) \quad (\text{VI-24})$$

In principle, three scenarios should be considered in the calculation of the path difference in favourable conditions δ_F

(see Figure VI.10). In practice, two formulae are sufficient:

- if the straight sound ray SR is masked by the obstacle (1st and 2nd case in Figure VI.10):

$$\delta_F = \hat{SO} + \hat{OR} - \hat{SR} \quad (\text{VI-25})$$

- if the straight sound ray SR is not masked by the obstacle (3rd case in Figure VI.10):

$$\delta_F = 2\hat{SA} + 2\hat{AR} - \hat{SO} - \hat{OR} - \hat{SR} \quad (\text{VI-26})$$

where A is the intersection of the straight sound ray SR and the extension of the diffracting obstacle.

For the multiple diffractions in favourable conditions:

- determine the convex hull defined by the various potential diffraction edges;
- eliminate the diffraction edges which are not on the boundary of the convex hull;
- calculate δ_F based on the lengths of the curved sound ray, by breaking down the diffracted path into as many curved segments as necessary (see Figure VI.11)

$$\delta_F = S\hat{O}_1 + \sum_{i=1}^{i=n-1} O_i\hat{O}_{i+1} + \hat{O}_n R - \hat{SR} \quad (\text{VI-27})$$

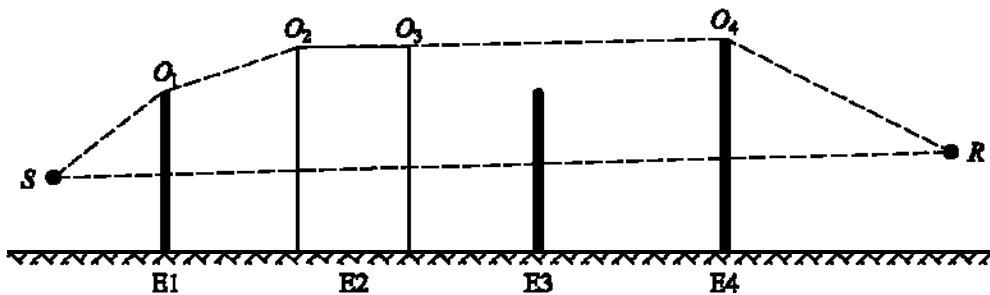


Figure VI.11 — Example of calculation of the path difference in favourable conditions, in the case of multiple diffractions

In the scenario presented in Figure V.12, the path difference is:

$$\delta_F = S\hat{O}_1 + O_1\hat{O}_2 + O_2\hat{O}_3 + O_3\hat{O}_4 + \hat{O}_4 R - \hat{SR} \quad (\text{VI-28})$$

VI.4.4.d. Calculation of the attenuation A_{dif}

The attenuation due to diffraction, taking the ground effects source side and receiver side into account, is calculated according to the following general formula:

$$A_{dif} = \Delta_{dif(S,R)} + \Delta_{ground(S,O)} + \Delta_{ground(O,R)} \quad (VI-29)$$

where

- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between the source S and the receiver R ;
- $\Delta_{ground(S,O)}$ is the attenuation due to the ground effect source side, weighted by the diffraction source side (see VI.4.4.d.1);
- $\Delta_{ground(O,R)}$ is the attenuation due to the ground effect receiver side, weighted by the diffraction receiver side (see VI.4.4.d.3).

VI.4.4.d.1. Calculation of the term $\Delta_{ground(S,O)}$

$$\Delta_{ground(S,O)} = -20 \lg \left(1 + \left(10^{-A_{ground(S,O)}/20} - 1 \right) \cdot 10^{-\left(\Delta_{dif(S',R)} - \Delta_{dif(S,R)} \right) / 20} \right) \quad (VI-30)$$

where

- $A_{ground(S,O)}$ is the attenuation due to the ground effect between the source S and the diffraction point O . This term is calculated as indicated in V.4.3.c in homogeneous conditions and in VI.4.3.d in favourable conditions, with the following hypotheses:
- $z_r = z_{o,s}$;
- G_{path} is calculated between S and O ;
- In homogeneous conditions: $G_w = G'_{path}$ in equation VI-17, $G_m = G'_{path}$ in equation VI-18;
- In favourable conditions: $G_m = G_{path}$ in equation VI-17, $G_m = G'_{path}$ in equation VI-18;
- $\Delta_{dif(S',R)}$ is the attenuation due to the diffraction between the image source S' and R , calculated as in VI.4.4.b;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between S and R , calculated as in VI.4.4.b.

VI.4.4.d.2. Calculation of the term $\Delta_{ground(O,R)}$

$$\Delta_{ground(O,R)} = -20 \lg_{10} \left(1 + \left(10^{-A_{ground(O,R)}/20} - 1 \right) \cdot 10^{-\left(\Delta_{dif(S,R')} - \Delta_{dif(S,R)} \right) / 20} \right) \quad (VI-31)$$

where

- $A_{ground(O,R)}$ is the attenuation due to the ground effect between the diffraction point O and the receiver R . This term is calculated as indicated in VI.4.3.c in homogeneous conditions and in VI.4.3.d in favourable conditions, with the following hypotheses:

- $z_s = z_{o,r}$;
- G_{path} is calculated between O and R ;

The G'_{path} correction does not need to be taken into account here as the source considered is the diffraction point. Therefore, G_{path} shall indeed be used in the calculation of ground effects, including for the lower bound term of the formula which becomes $-3(1 - G_{\text{path}})$.

- In homogeneous conditions, \bar{G}_W in equation VI-17 (and \bar{G}_M in equation VI-18) is equal to G_{path} ;
- In favourable conditions, \bar{G}_W in equation VI-17 (and \bar{G}_M in equation VI-18) is equal to G_{path} ;
- $\Delta_{\text{dif}(S,R)}$ is the attenuation due to the diffraction between S and the image receiver R' , calculated as in VI.4.2;
- $\Delta_{\text{dif}(S,R)}$ is the attenuation due to the diffraction between S and R , calculated as in VI.4.4.b.

VI.4.4.e. Vertical edge scenarios

Equation 31 may be used to calculate the diffractions on vertical edges (lateral diffractions). If this is the case, $A_{\text{dif}} = \Delta_{\text{dif}(S,R)}$ is taken and the term A_{ground} is kept. In addition, A_{atm} and A_{ground} shall be calculated from the total length of the propagation path. A_{div} is still calculated from the direct distance d . Equations V-8 and V-6 respectively become:

$$A_{i,H} = A_{\text{div}} + A_{\text{atm}}^{\text{path}} + A_{\text{ground},H}^{\text{path}} + \Delta_{\text{dif},H(S,R)} \quad (\text{VI-32})$$

$$A_{i,F} = A_{\text{div}} + A_{\text{atm}}^{\text{path}} + A_{\text{ground},F}^{\text{path}} + \Delta_{\text{dif},H(S,R)} \quad (\text{VI-33})$$

Δ_{dif} is indeed used in homogeneous conditions in equation VI-33.

VI.4.5. Reflections on the vertical obstacles

VI.4.5.a. Attenuation through absorption

The reflections on vertical obstacles are dealt with by means of image sources. Reflections in building façades and noise barriers are thus treated in this way.

An obstacle is considered to be vertical if its slope in relation to the vertical is less than 15° .

When dealing with reflections on significantly sloping obstacles, the method should then be applied in 3D.

The obstacles where at least one dimension is less than 0,5 m shall be ignored in the reflection calculation, except for special configurations¹².

It is reminded that the reflections on the ground are not dealt with here. They are taken into account in the calculations of attenuation due to the boundary (ground, diffraction).

If L_w is the power level of the source S and α_r the absorption coefficient of the surface of the obstacle, then the power level of the image source S' is equal to:

¹² A network of small obstacles in a plane and at regular intervals constitutes one example of a special configuration.

$$L_{W'} = L_W + 10 \lg(1 - \alpha_r) \quad (\text{VI-34})$$

where $0 \leq \alpha_r < 1$

The propagation attenuations described above (see VI.4.1 to VI.4.4) are then applied to this path (image source, receiver), as for a direct path.

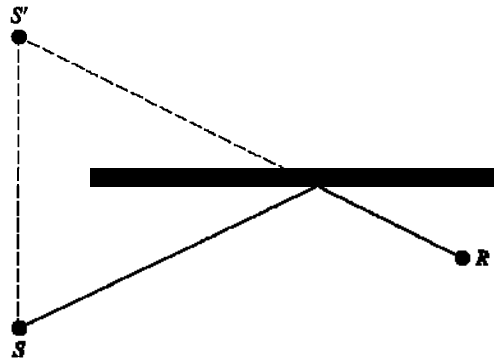


Figure VI.12 — Specular reflection on an obstacle dealt with by the image source method (*S*: source, *S'*: image source, *R*: receiver)

VI.4.5.b. Attenuation through retrodiffraction

In the geometrical research of sound paths, during the reflection on a vertical obstacle (barrier wall, building), the position of the impact of the ray in relation to the upper edge of this obstacle determines the more or less significant proportion of energy effectively reflected. This loss of acoustic energy when the ray undergoes a reflection is called attenuation through retrodiffraction.

In the case of multiple reflections between two vertical walls, not taking this retrodiffraction phenomenon into account results in overestimating the sound level calculated, with this overestimation increasing at the same time as the order of reflection considered.

If the case of a trench is taken, for example (see Figure V.13), the attenuation through retrodiffraction shall be applied to each reflection on the retaining walls.

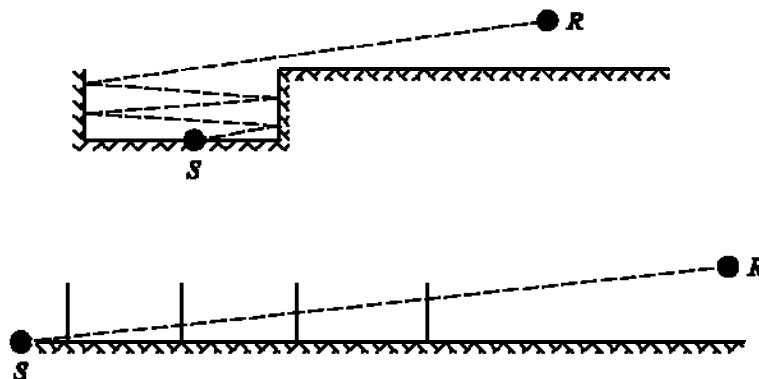


Figure VI.13 — Sound ray reflected to the order of 4 in a track in a trench actual cross-section (top), unfolded cross-section (bottom)

In this representation, the sound ray reaches the receiver “by successively passing through” the retaining walls of the trench that can therefore be compared to openings.

When calculating propagation through an opening, the sound field at the receiver is the sum of the direct field and the field diffracted by the edges of the opening. This diffracted field ensures the continuity of the transition between the clear area and the shadow area. When the ray approaches the edge of the opening, the direct field is attenuated. The calculation is identical to that of the attenuation by a barrier in the clear area.

The path difference δ' associated with each retrodiffraction is the opposite of the path difference between S and R relatively at each upper edge O, and this in a view according to a deployed cross-section (see Figure VI.14).

$$\delta = -(SO + OR - SR) \quad (\text{VI-35})$$

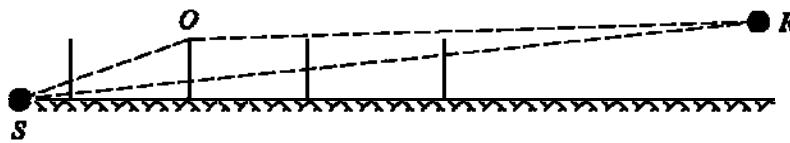


Figure VI.14 — Calculation of the path difference for the second reflection

The “minus” sign of equation VI-35 means that the receiver is considered here in the clear area.

Attenuation through retrodiffraction Δ_{retrodif} is obtained by equation VI-36 which is similar to equation VI-21 whose notations are reworked.

$$A_{\text{retrodif}} = \begin{cases} 10C_h \log_{10} \left(3 + \frac{40}{\lambda} \delta' \right) & \text{if } \frac{40}{\lambda} \delta' \geq -2 \\ 0 & \text{otherwise} \end{cases} \quad (\text{VI-36})$$

This attenuation is applied to the direct ray each time it “passes through” (reflects on) a wall or building. The power level of the image source S' therefore becomes (see equation VI-37):

$$L_{W'} = L_W + 10 \lg(1 - \alpha_r) - \Delta_{\text{retrodif}} \quad (\text{VI-37})$$

In complex propagation configurations, diffractions may exist between reflections, or between the receiver and the reflections. In this case, the retrodiffraction by the walls is estimated by considering the path between source and first diffraction point R' (therefore considered as receiver in equation VI-35). This principle is illustrated in Figure 15.

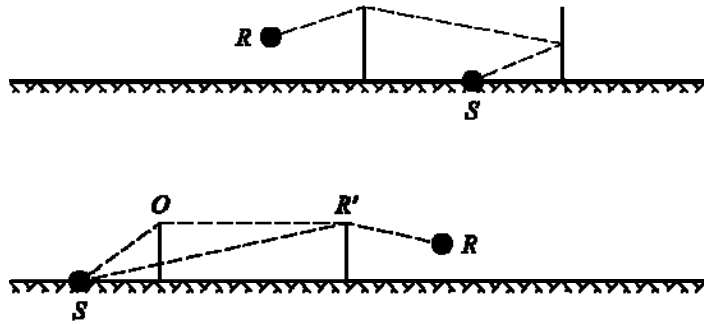


Figure VI.15 — Calculation of the path difference in presence of a diffraction actual cross-section (top), unfolded cross-section (bottom)

References

- [1] Normalisation française, NF-S 13-133, Acoustique - Bruit des infrastructures de transports terrestres - Calcul de l'atténuation du son lors de sa propagation en milieu extérieur, incluant les effets météorologiques - 2011

CHAPTER VII. AIRCRAFT NOISE PREDICTION

VII.1. The component of CNOSSOS-EU for aircraft noise

In order to match the objectives of the END and in the context of the preparation of common noise assessment methods in EU (CNOSSOS-EU), the European Commission tries to take benefit from the best existing noise assessment methods and knowledge worldwide. For this purpose, the European Commission's Joint Research Centre (JRC) in liaison with the Directorate General for the Environment (DG ENV) and European Environment Agency (EEA) organised on 19-20 January 2010 in Brussels an ad hoc workshop on "*Aircraft Noise Prediction*" with the aim to discuss among EU experts about the aircraft noise module of CNOSSOS-EU.

This workshop was a follow-up of the Workshop on the "*Selection of common noise assessment methods in EU*" previously organised by JRC, DG ENV and the EEA which took place on 8-9 September 2009 in Brussels. Among the recommendations of that Workshop, was to take as basis for the aircraft module of the CNOSSOS-EU method the Document 29 (3rd Edition) of the European Civil Aviation Conference (ECAC). Some potential improvements were identified and further discussed during the workshop on "*Aircraft Noise Prediction*" in January 2010. These were mainly concerned with considering the use of some features of the German AzB method for improving the ECAC Doc.29, 3rd Edition method.

During the Workshop's discussions, it was recognised that aircraft noise modelling is specific compared to the other three noise sources (road traffic, railway traffic and industrial). There is long-standing experience in aircraft noise assessment, and prediction methods together with associated performance databases that have been established and defined at international level. However, it was recognised that for some of the issues discussed, there is an opportunity to improve in the existing methods and procedures.

The representatives of the European Commission and the aircraft noise experts participated in the Workshop, recognised that worldwide resources to develop and maintain aircraft noise modelling tools are limited and as such, it is critical to increase synergies among the stakeholders affected and maximise commonality of both, the methodology and the input data.

Following the formal creation of a CNOSSOS-EU Technical Committee in November 2010, an aircraft noise specific working group (WG 4) was tasked with continuing the previous work and making formal recommendations on the calculation method. WG 4 held two meetings, one in February 2011 and one in May 2011. This chapter summarises the recommended methodology and the associated recommendations made by CNOSSOS-EU WG 4.

VII.2. Recommended methodology

VII.2.1. Fixed-wing aircraft noise calculation methodology and noise & performance database

WG4 reviewed the two previous candidate methodologies, ECAC Doc. 29 3rd Edition and AzB 2008. The two methodologies define two different noise and performance database structures. The ICAO ANP database has been developed to fulfil the requirements of ECAC Doc. 29. A national database has been developed to accompany AzB 2008.

A significant requirement of the methodology is that it must also be used by Directive 2002/30/EC, the airport operating restrictions Directive. This requires that the methodology and supporting database be able to assess policy options at an airport such as fleet changes and changes of noise abatement procedures. Whilst the review noted that AzB 2008, in particular its database could be developed over time to meet these needs, Doc. 29 and the ANP database were better suited to the additional requirements imposed by Directive 2002/30/EC at this time.

Secondly, it was noted that ECAC Doc. 29 3rd Edition is consistent with ICAO Doc. 9911. As an agency of the Commission, EASA will use the CNOSSOS-EU methodology for European regulatory impact assessment, e.g. changes of ICAO noise standards. There is therefore a need to ensure the CNOSSOS-EU method is aligned with the ICAO method.

ECAC Doc. 29 3rd Edition (Dec 2005) and the ICAO ANP database version 2 are therefore recommended as the aircraft noise calculation method and database for incorporation into Annex II.

VII.2.2. ECAC Document 29 3rd Edition

The fundamental calculation methodology in Doc. 29 has evolved over several decades. It includes an aircraft performance model so that the source location is calculated as a function of aircraft type, weight and operating procedure. These parameters have a significant effect on the location of the source and hence the sound propagation distance. As already noted these parameters will often be varied to mitigate aircraft noise and also to assess the effects of operating restrictions using Directive 2002/30/EC.

Once the geometry of the aircraft source is established (using the performance model), sound exposure is calculated using Noise Power Distance (NPD) data. Acoustic data is stored as a function of both source emission and propagation distance, the latter incorporating both spherical spreading and air absorption together. The stored NPD data represent noise associated with an infinitely long flight path where flight path parameters remain constant. Various corrections are applied to the infinite flight path noise level to correct for varying flight path parameters, i.e. speed, height, power and propagation distance, in order to calculate the noise contribution for each flight path segment.

Because the NPD data is already two-dimensional (power and distance), it was historically considered more efficient to store the data in an aggregated A-weighted form, rather than a 1/3 octave band format. This does not mean to say that the recommended method is not a 1/3 octave band method. NPDs are developed from 1/3 octave band, assuming a reference atmosphere for sound absorption. In most cases this will be sufficient for strategic mapping

purposes. However, the calculation methodology includes a process by which the reference atmosphere may be adapted to local conditions. To enable this process, a 1/3 octave band spectrum is defined for each aircraft and for take-off and landing separately. This spectrum is used to re-calculate the NPD data for any specific meteorological conditions, thereby fully incorporating the principles of a 1/3 octave band calculation method as applied to the other sources covered by the Directive.

VII.2.3. Adaptation of the ANP database to local meteorological conditions

Local meteorological conditions affect both aircraft performance as well as sound propagation. The effect on aircraft performance is to alter the effective source power and the location of the source. The location of the source is generally of much greater importance than the meteorological effect on sound propagation.

The default air temperature is 15 degC and a headwind of 8kt (4.1m/s). The aircraft performance calculation methodology described in Doc. 29 3rd Edition Vol. 2 Appendix B directly permits the use of local temperature and headwind speed on aircraft performance and thus source location in the vertical plane.

Sound absorption rates vary depending on temperature and relative humidity. The noise data provided in the ANP database are based on average sound absorption rates for a range of typical airport conditions and thus do not represent a single set of temperature and humidity values. However, Doc. 29 Vol. 2 Appendix D describes a method for re-processing the NPD data to specific local temperature and relative humidity values. The January 2010 workshop recommended that the NPD data should be adapted to local conditions as standard practice.

In order that this procedure is performed competently and consistently, guidance is required on the procedure to be applied and the fidelity/resolution of the meteorological data required. This has yet to be developed and will need to consider both seasonal meteorological effects and day, evening, night effects because of the weightings incorporated into the L_{DEN} index.

[Note: At the Noise Regulatory Committee (NRC) meeting which took place on 18 May 2011 in Bruxelles, the additional resource required to make meteo adaptations was questioned. Members of CNOSSOS-EU WG 4 are reluctant to commit resource to the development of guidance if the need for adaptation may be dropped and guidance not needed].

VII.2.4. Aerodrome/Airport coverage (Article 3 item (p))

Members of WG 4 reported significant variation in interpretation of Article 3 item (p) in terms of aerodromes and airports covered. Although noted as being beyond the terms of reference of WG 4, it was noted that if a major aspect of CNOSSOS-EU is the aim to increase standardisation across EU MS, then consistent treatment as to the aerodromes/airports covered is as important as calculation methodology. The variability identified centred on aerodromes inside agglomerations, but below 50,000 movements, the inclusion of helicopter operations and heliports, and the inclusion of military operations where at civilian airports identified by the Directive.

Since the aim is to comprehensively map noise inside agglomerations, it was agreed that all aerodromes inside agglomerations should be included, regardless of size. Secondly, helicopter operations should be included at airports covered by the Directive where significant. Secondly, dedicated helicopter aerodromes (heliports) inside agglomerations should also be included.

Although the Directive specifically excludes military aircraft noise, it was noted there are some civilian airports covered by the Directive where military aircraft noise dominates. For such cases where there is a significant noise contribution from military aircraft, these should be included to obtain a complete picture of the aircraft noise environment.

All of the recommendations impose additional requirements on the calculation method and supporting data. These are discussed in turn.

VII.2.5. General aviation noise and performance database

Whilst there are an isolated number of general aviation aircraft in the ICAO ANP database, coverage is insufficient. It is therefore proposed to incorporate general aviation data from the AzB 2008 database, converting it to the format required for use with ECAC Doc. 29 3rd Edition. It is proposed that the additional data to supplement ANP version 2 be published by the Commission along with the guidance on applying the recommended method.

VII.2.6. Rotary aircraft (helicopter) noise calculation methodology and noise & performance database

Unlike for fixed-wing aircraft noise, there is at present no internationally agreed helicopter noise calculation methodology. Helicopter noise is highly complex, with multiple discrete sources, contributing broadband and tonal noise. A promising development is the European HELENA helicopter noise model. At present the model includes data for only four helicopters, and therefore cannot be recommended for incorporation into Directive 2002/49/EC. It is recommended that development of the HELENA model and the acquisition of noise and performance data is encouraged with the aim of being developed in the long-term as the European and ultimately global helicopter noise calculation methodology.

The other alternative, at present, is to exclude helicopter noise altogether until a viable method is developed with supporting data. That was considered unacceptable and thus the compromise position recommended, as an 'interim method', is to apply the fixed-wing noise calculation methodology to helicopters, but with helicopter specific noise and performance data. It is proposed that the ANP database is supplemented with helicopter noise and performance data from AzB 2008 or from a Member States existing national method. The supplemental data would then be published by the Commission along with guidance on its application. Further effort on helicopter data development is dependent on a decision from the NRC that helicopter noise should be included within the Directive.

VII.2.7. Military aircraft noise calculation methodology and noise & performance database

Some military transport aircraft, derived from civil aircraft, are already included in the ICAO ANP database. However, there are notable military transport aircraft omissions. Secondly, there is a need in some cases for the inclusion of data for military fighter aircraft. It is therefore proposed to supplement the ICAO ANP database version 2 with data for military aircraft from both the INM/Noisemap and AzB databases.

In terms of calculation methodology, ECAC Doc. 29 3rd Edition will be used, but in the case military fighter aircraft, they will be modelled assuming no noise shielding effects (in practice this means modelling the aircraft as though it is a propeller aircraft).

It is noted that in some MS, proprietary noise and performance data exists that may be more applicable than the recommended default, yet the data cannot be shared due to the proprietary nature of some military aircraft noise data. In such cases MS should be permitted to use this data. WG4 also recommends that the Noise Regulatory Committee encourage MS to share data and collaborate to provide common data for the purposes of military aircraft noise calculation where operating at civil airports. Further effort on military aircraft data development is dependent on a decision from the NRC that helicopter noise should be included within the Directive.

VII.2.8. Definition of fixed-wing aircraft ground noise

Extensive discussion took place on the possible inclusion of aircraft ground noise. In some isolated cases, it is believed that some elements of aircraft 'ground' noise were included in first round mapping. Since aircraft 'air' noise includes noise whilst an aircraft is on the ground during take-off and landing, ground noise could include all other aircraft noise. e.g. taxi noise, APU noise and engine run-up (testing) noise. WG 4 concluded that engine run-up noise was the most significant aspect of aircraft 'ground' noise since a proportion of engine testing is often done at night. WG 4 therefore recommended that engine run-up (testing) noise be included in aircraft noise maps.

VII.2.9. Ground noise calculation methodology and noise & performance database

Recognising that the problem of engine run-up noise is essentially a ground-based fixed point source, it was concluded that engine run-up noise should be modelled with the same ground-based sound propagation methodology as for industrial noise. It is therefore proposed that engine run-up emission and directivity data be derived and compiled from the ICAO ANP database information. This will include a source spectrum for each power setting and a directivity pattern. Guidance will then be provided on the application of this data in conjunction with the Industrial noise calculation method.

At the NRC meeting which took place on 18 May 2011 in Bruxelles, concern was raised on the potential for significant added expense/resource for little overall contribution, except for very isolated circumstances. Further effort on developing this dataset and any accompanying guidance on its application is therefore dependent on a decision from the NRC that engine run-up ground noise should be included within the Directive.

- The effect of moving the receiver point to 4 m high (at the moment, ANP data are recorded at 1.2 m high)

- 4.0 m is the required position in END for all four noise sources (road traffic, railway traffic, aircraft and industry)
- The existing evidence shows that in general the difference between 1.2 m and 4.0 m is well below 1 dB for soft grounds and angles of incidence above 15°. Over reflecting ground and for lower angles of incidence, there is no clear evaluation at the moment of the difference.
- Even if the difference is small, the number of affected people may vary significantly (possibly tens of thousands of people). Thus, any correction value or methodology chosen will need a strong evidence base.
- It is, therefore, recommended to state in CNOSSOS-EU that the height of the assessment point may have an influence but for the time being and in the transition time a default correction of zero will be accepted and existing NPD data at 1.2 m will be accepted (see above).

- Consideration of sound reflections on the ground

- The existing evidence shows that, in general, a difference exists between different ground types because of the change in the absorption factor, and measurements confirm that it can be up to 2-3 dB in the overall (A) weighted level.
- It is also recognised that, at the moment, more evidence is needed to propose a correction for ground reflection and that correction is suggested to be avoided because of: (a) the increase in the calculation times; (b) the difficulty to gather input values on ground type and (c) the impact that a fragmented noise contour may have when communicated to the public.
- It is recommended to state in CNOSSOS-EU that, the ground absorption factor may have an influence. It was suggested this issue to be further investigated and other alternative approaches to be possibly considered as well before any methodology is considered for implementation.

- Consideration of screening effects and reflections on vertical obstacles

- It is recognised that the presence of vertical reflecting objects close to the receiver may have an effect on noise which sometimes can be positive or negative.
- The inclusion of screening/reflections on obstacles would result in much longer calculation times (and is thus impractical to consider) due to a much finer resolution grid and more input data about these obstacles, which is not available in some EU MS. Therefore, it is recommended not to consider these obstacles' screening and reflection effects in CNOSSOS-EU.

VII.2.10. Specific issues and recommendations regarding the aircraft noise emission database

➤ Validation of aircraft noise predictions

- EC is interested in assessing noise in residential areas and supports the definition of accurate guidelines that can allow for validation of predictions in such areas. Such validation is however dependent on an agreed process for the collection and processing of noise measurements.
- More comparisons between measurements and calculations should be produced and published, provided a comparison process can be agreed.
- A common validation procedure of aircraft noise calculations should be established.

VII.2.11 Generic recommendations regarding the aircraft prediction methodology

- ECAC Doc. 29, 3rd Edition (2005) will be adopted as the common method for strategic noise maps for aircraft noise in EU (i.e. the aircraft module of CNOSSOS-EU), and a process will be put in place to consider proposed modifications/amendments of ECAC Doc. 29 3rd Ed.
- The fixed-wing calculation method will also apply to GA aircraft, helicopters and military aircraft. Supplemental data will be provided, along with guidelines of application for GA, helicopter and military aircraft. For the special case of military fighter aircraft, no engine noise shielding shall be assumed.
- Engine run-up (ground noise) will be included in noise strategic noise maps. This will be calculated using the Industrial noise calculation module of CNOSSOS-EU. The required input data will be derived from the ANP database (see databases below).
- European Commission will take ownership and oversight of any process for maintaining, developing (including the software implementation) and disseminating the CNOSSOS-EU. It is strongly desirable to reach agreement at international level which could best be achieved through the ICAO environmental committee, CAEP, and involve all relevant European stakeholders (DG ENV, DG TREN, DG JRC, EU MS, EASA, EEA) associated to the implementation of the END.
- A provision to permit modellers to use the updated versions of the CNOSSOS-EU including the aircraft noise module should be proposed if published in between any reviews of the END (e.g. Adaptation to Technical Progress process to be included in the review of the END).

VII.2.12. Generic recommendations regarding the aircraft noise and performance database:

- The ICAO Aircraft Noise and Performance (ANP) Database version 2 (2011) is currently the best candidate for achieving a global consensus on an aircraft noise and performance input database.
- It is the only database that fully meets the requirements of assessing noise restrictions in accordance with Directive 2002/30/EC.
- Use of a standardised database should ensure consistent predicted noise impacts across all EU Member States, notwithstanding differences in aircraft operating procedures across airlines and sometimes airports.
- A robust validation process of ANP data should be formalized at the ICAO level. In particular, significant improvements are required in the approval process for aircraft noise and performance data to ensure high quality model input, and to avoid potential discrimination between aircraft manufacturers.
- Due to the international nature of the aviation industry, all data should be reviewed and approved against an agreed set of international requirements. This could build on existing European (EASA) - US (FAA) approval processes, such as that for aircraft noise certification, in order to benefit from significant synergies.
- The ANP database should be supplemented with data for additional GA aircraft, helicopter and military aircraft operating at Community airports.
- A database to facilitate the calculation of ground noise from engine run-up (testing) should be included..
- An international agreement could best be achieved through the ICAO environmental committee, CAEP, and would involve all relevant stakeholders including the DG ENV, DG TREN, DG JRC, EASA and EU Member States.
- Transition issues for EU Member States should also be taken into account in moving towards a common noise modelling methodology/database. As such, proposed future plans should be communicated as soon as possible.

CHAPTER VIII. ASSIGNING NOISE LEVELS AND POPULATION TO BUILDINGS

VIII.1. Background and Definitions

VIII.1.1. Background

Directive 2002/49/EC (Environmental Noise Directive (END)) requires Member States to report information based upon strategic noise maps to the Commission, including the statistics referred to in Annex VI. A phase of modelling to assess exposure to noise will often be undertaken to estimate these statistics.

In order to complete a fit for purpose exposure assessment:

- the manner in which the information will subsequently be applied;
- the key terms and definitions; and
- the methods and approaches to be applied

should all be defined in the first instance.

As indicated in the second item above, for the purposes of completing the exposure assessments required to report the information identified in Annex VI of the END, a variety of terms may need to be defined or clarified further. These terms and potential definitions are summarized below.

The definitions will need to be adapted and expanded to reflect the detail of the recommended noise exposure assessment methods being applied for the assignment of population to receiver points at the facades of buildings.

The potential definitions, listed below are merely an interpretation of the terms referencing relevant UK definitions, currently in place and cannot accurately reflect or describe the reporting or legal requirements of the Commission. The various definitions and methods will need to be revised to reflect the precise requirements of the Commission, the way the results will be applied, and the requirements of other CNOSSOS-EU Working Groups, and the work of the EEA.

VIII.1.2. Definitions

Annex VI of the END requires that “the estimated number of **people** living in **dwellings**” exposed to various noise levels “4 m above the ground on the **most exposed façade**” is provided for various scenarios.

For the purposes of completing population exposure assessments to report this information, the terms ‘people’, ‘dwellings’, ‘most exposed façade’ and their related terms may need further definition and clarification.

VIII.1.2.1. *Persons / People / The Public*

For the purposes of the statistics required by Annex VI, persons (or people) can be defined as “human” beings, thus being consistent with the scope of the END defined in Article 2, paragraph 1. They are members of “the public” as defined in Article 3 (v) as “one or more

natural or legal persons and, in accordance with national legislation or practice, their associations, organizations or groups”

VIII.1.2.2. Population

The term population is not referred to by the END in the context of any noise exposure assessment statistics to be reported as required by Annex VI. The definitions here therefore do not attempt to reflect the definition of terms such as population, inhabitants or residents.

It is of note that population exposure assessments, estimating the number of people living in dwellings, as defined above do not directly assess the exposure of people. The exposure assessment is effectively carried out upon the building/dwelling, not the individual. In any application of the statistics it is important to note that there is no attempt to reflect the temporal dimension of the movement of population in this exposure assessment.

VIII.1.2.3. Dwelling

For the estimation of the number of people living in dwellings, in Annex VI, the term dwelling can be defined as:

- “a self-contained unit of accommodation” (UK Census 2001).
 - Self-containment is where all the rooms (including kitchen, bathroom and toilet) in a household's accommodation are behind a single door which only that household can use

The dwelling may be within permanent structure, or a non-permanent structure, such as caravans, mobile homes, converted railway carriages and houseboats, if the non-permanent building is used as permanent residence, is static, and has mains supplied services such as electricity, water and telephone.

A structure may contain one dwelling, such as a detached house, or multiple dwellings, such as semi-detached houses, terrace houses, flats, maisonettes, apartments etc.

Invariably an individual dwelling can also be defined as a household, where a household can be defined as comprising one person living alone, or a group of people living at the same address (UK Census 2001).

The use of “dwellings” within the END, see Appendix VIII-A, indicates that vacant or unoccupied dwellings should be included within the assessment of exposure of dwellings, but not within the assessment of exposure of people if the dwellings are known to be vacant, as this is contra to the phrasing used, e.g. “how many persons in the above categories live in dwellings that have” and “The estimated total number of people (in hundreds) living in dwellings”.

VIII.1.2.4. Building

The term building is not referred to directly in the context of the exposure assessments required by Annex VI.

The UK Building Regulations 2010 define “building” as:

- any permanent or temporary building but not any other kind of structure or erection, and a reference to a building includes a reference to part of a building;

A building may contain zero, one or more individual dwellings or households. Residential buildings can therefore be considered to be those buildings containing one or more individual dwellings. Noise-sensitive buildings may be considered those buildings which contain dwellings, or which have uses which the competent authority deems to be noise sensitive, such

as schools or other educational establishments, hospitals, nursing homes, places of public worship, libraries etc.

VIII.1.2.5 Façade

The façades of a dwelling shall consist of all externally facing walls.

Annex I, 1 defines the L_{den} using the stated formula, and in which:

- “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**”

This indicates that the subsequent references to façade indicate **the façade of the dwelling under consideration**. Which would be consistent with Annex III regarding dose-response relationships: “dwellings with a quiet façade as defined in Annex VI”.

VIII.1.2.6. Most exposed façade

Annex I, 1 states:

- “the most exposed façade; for this purpose, the most exposed façade will be the external wall facing onto and nearest to the specific noise source; for other purposes other choices may be made”

Subsequent practical experience has demonstrated that selection of the most exposed façade based upon distance may lead to contradictory situations. For this reason a revised a definition is proposed:

- the most exposed façade will be the external wall of the dwelling exposed to the highest value of L_{den}/L_{night} from the specific noise source under consideration (e.g. road traffic).

The proposed definition is also more consistent with the existing definition of quiet façade, see below.

VIII.1.2.7. Quiet façade

Annex VI, 1.5 states:

- “a quiet façade, meaning the façade of a dwelling at which the value of L_{den} four metres above the ground and two metres in front of the façade, for the noise emitted from a specific source, is more than 20 dB lower than at the façade having the highest value of L_{den} .”

VIII.2. Assigning noise levels and population to buildings

Preliminary remark:

For the needs of Strategic Noise Mapping, only those individuals which correspond to the people officially registered as residents - as per the latest official statistical data bank for each registered building or block unit (as per each member state relevant regulations) is to be used (and not including those having a second address, or being simply owners of a dwelling etc..).

Simultaneously, it has to be accepted that some individuals may be recorded as residents though they are not effectively living in the dwelling for the given annual time period. Those potential errors are considered of a minor importance and therefore are acceptable.

Moreover, only buildings including residents (i.e.: no schools, hospitals, or other public or special use buildings) are to be used for population assignment

VIII.2.1. Determination of the number of inhabitants of a building

The number of inhabitants of a residential building is an important intermediate parameter for the estimation of the exposure to noise. Unfortunately, data on this parameter is not always available. Below it is specified how this parameter can be derived from data more readily available:

Symbols used in the following:

- BA = base area of the building
- DFS = dwelling floor space
- DUFS = dwelling unit floor space
- H = height of the building
- FSI = dwelling floor space per inhabitant
- Inh = number of inhabitants
- NF = number of floors
- V = volume of residential buildings

VIII.2.1.1. CASE 1: Data on the number of inhabitants is available

1A: The number of inhabitants is known on the basis of dwelling units. In this case the number of inhabitants of a building is the sum of the number of inhabitants of all dwelling units in the building:

$$Inh_{building} = \sum_{i=1}^n Inh_{dwellinguniti}$$

1B: The number of inhabitants is known only for entities larger than a building, e.g. city block sides, city blocks, districts or even an entire municipality. In this case the number of inhabitants of a building is estimated based on the volume of the building:

$$Inh_{building} = \frac{V_{building}}{V_{total}} \times Inh_{total}$$

The index 'total' here refers to the respective entity considered. The volume of the building is the product of its base area and its height.

$$V_{building} = BA_{building} \times H_{building}$$

If the height of the building is not known it can be estimated based on the number of floors $NF_{building}$ assuming an average height per floor of 3 metres:

$$H_{building} = NF_{building} \times 3m$$

If the number of floors is also not known a default value for the number of floors representative for the district or the borough shall be used.

The total volume of residential buildings in the entity considered V_{total} is calculated as the sum of the volumes of all residential buildings in the entity:

$$V_{total} = \sum_{i=1}^n V_{building_i}$$

VIII.2.1.2. CASE 2: No data on the number of inhabitants is available

In this case the number of inhabitants is estimated based on the average dwelling floor space per inhabitant FSI. If this parameter is not known a national default value shall be used.

2A: The dwelling floor space is known on the basis of dwelling units. In this case the number of inhabitants of each dwelling unit is estimated as follows:

$$Inh_{dwellingunit_i} = \frac{DUFF_i}{FSI}$$

The number of inhabitants of the building can now be estimated as in CASE 1A above.

2B: The dwelling floor space is known for the entire building, i.e. the sum of the dwelling floor spaces of all dwelling units in the building is known. In this case the number of inhabitants is estimated as follows:

$$Inh_{building} = \frac{DFS_{building}}{FSI}$$

2C: The dwelling floor space is known only for entities larger than a building, e.g. city block sides, city blocks, districts or even an entire municipality.

In this case the number of inhabitants of a building is estimated based on the volume of the building as described in CASE 1B above with the total number of inhabitants estimated as follows:

$$Inh_{total} = \frac{DFS_{total}}{FSI}$$

2D: The dwelling floor space is unknown. In this case the number of inhabitants of a building is estimated as described in CASE 2B above with the dwelling floor space estimated as follows:

$$DFS_{building} = BA_{building} \times 0.8 \times NF_{building}$$

The factor 0.8 is the conversion factor *gross floor area* → *dwelling floor space*. If a different factor is known to be representative for the area it should be used instead.

If the number of floors of the building is not known, it shall be estimated based on the height of the building, H_{building} , typically resulting in a non-integer number of floors:

$$NF_{\text{building}} = \frac{H_{\text{building}}}{3\text{m}}$$

If neither the height of the building nor the number of floors is known a default value for the number of floors representative for the district or the borough shall be used.

NOTE: FSI estimation

It is known from experience, that in Germany the „dwelling space per inhabitant“ in the very most cases is only from the level „side of city block“ upwards available. Statistical offices in Germany are recording current information.

The Federal Statistical Office specifies for the year 2006, e.g. the following mean values:

Former federal territory without Berlin:

FSI = 44 m² dwelling space per inhabitant

New federal lands including Berlin:

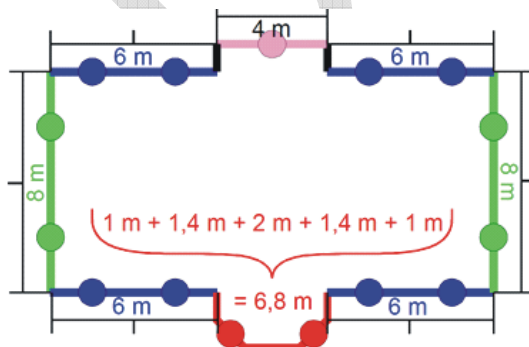
FSI = 38 m² dwelling space per inhabitant

VIII.2.2. Assigning receiver points to the façades of buildings

The assessment of population exposure to noise is based on receiver point levels at 4 m above terrain level in front of building façades of residential buildings.

The proposed methodology is based on the German regulation VBEB¹³ with some amendments that will better match the list of demands.

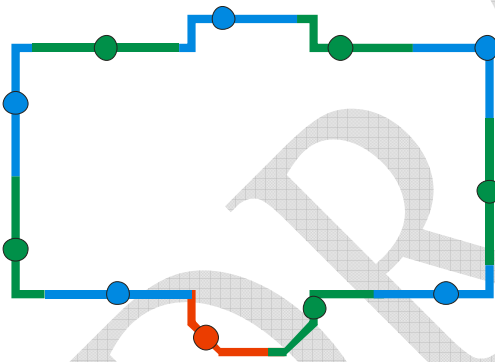
The following figure reflects the approach:



¹³ Vorläufige Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm (VBEB), Federal Ministry of the Environment (07.02.2007)

- a) Segments of a length of more than 5 m are split up in regular intervals of the longest possible length, but less or equal to 5 m. Receiver points are placed in the middle of each regular interval (**blue/green**).
- b) Remaining segments above a length of 2.5 m are represented by one receiver point in the middle of each segment (**pink**).
- c) Remaining subsequent segments with a total length of more than 5 m, are treated as polyline object in a similar manner as described in a) and b) (**red**).
- d) The influence of any receiver position, for instance the number of inhabitants distributed to this position, will be weighted by the length of the represented façade.
- e) For buildings with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of inhabitants.
- f) For other buildings statistics use all receiver points in a weighted manner, so that the sum of all receiver points represents the total number of inhabitants

Alternative:



- a) Façades are split up every 5 m from start position on with a receiver position placed at half distance (**blue/green**).
- b) The remaining section gets its receiver point in its middle (**red**).
- c) For buildings with floor sizes that indicate a single dwelling per floor level, the most exposed façade noise level is directly used for the statistics and related to the number of inhabitants
- d) For other buildings statistics use all receiver points in a weighted manner, so that the sum of all receiver points represents the total number of inhabitants

VIII.3. Methodological aspects of the voluntary application for action planning

VIII.3.1. Introduction

This document defines a methodology for the assignment of population to receiver points at the facades of buildings. While the former chapters focus on this task in the context of noise mapping, this chapter addresses the same task in the context of action planning. Some aspects of the task depend on the context of the assignment and therefore differ as described below.

In the context of the mandatory application for noise mapping, the guiding principle is consistency to guarantee comparability between member states. In contrast, in the context of the voluntary application for action planning the sensitivity to the noise mitigation measures under consideration is the key factor for the correct assessment of the benefits of these measures.

Action plans are typically developed for areas of limited extent, where a noise conflict is found or feared to develop. This allows and calls for a much more detailed approach than is reasonable for large scale noise mapping. In local action planning, specific local aspects and assessment parameters determine which level of detail should be used and different platforms of investigation may be adopted, especially aiming at the best adapted assignment of the population to receiver points. It is therefore not sensible to prescribe a general method for the local assignment task, but rather in the nature of local action planning to design a flexible frame work allowing for local adaptation considering local aspects of life and environmental quality.

Noise is an important environmental factor contributing to the degradation of the urban environment and the quality of life. In some EU member states, especially in Southern Europe, relevant urban development plans do not include noise as a design parameter, except in certain cases (e.g. protection of special buildings).

The structure and rhythm of each European city are very important factors determining the city's dynamics and soundscape, which are part of the city's signature. The behavior of the people living in the city and the climatic conditions require an objective approach of the existing acoustic environment introducing noise factor as psycho-social and design parameter of urban planning. Especially in the countries of Southern Europe, the open space is dominated by urban environmental noise corresponding to the diurnal 'rhythm' of life and recreational activities of urban centers. It is the major cause of residential dissatisfaction as far as the environment and quality of life are concerned. The lifestyle characteristics invade the vast majority of open and private spaces and cause annoyance. Consequently, the struggle against urban noise may need a more specific approach.

Therefore, it seems useful to address some common aspects and to give guidance for typical applications taking into account local parameters that may be a cause of altering common noise assessment tools.

VIII.3.2. Specific aspects

For the sake of consistency, some general specifications are defined in the preceding chapters. While they are sensible in the context of noise mapping they may not be appropriate in general for local action planning as explained below.

VIII.3.2.1. Assessment height

For noise mapping, the height of the receiver points at the facades of buildings is fixed at 4 m above ground. Depending on the specific situation under investigation, a different assessment height may lead to a better estimate of the exposure. For example, the attenuation effect of a noise barrier may provide adequate shielding for the lower floors of a multi-storey building while the upper floors remain largely unprotected. In this situation, the assignment of all inhabitants of the building to receiver points at a height of 4 m results in an underestimate of the exposure and an overestimate of the mitigation effect of the noise barrier. The opposite effect occurs in the situation of a high rise building right next to a busy road. While the upper floors may experience only little exposure to noise the ground floor and lower levels – often occupied by businesses – may be severely affected by noise. The assignment of all inhabitants to the 4 m level results in an overestimate of the exposure.

The choice of the height of the receiver points can have a substantial influence on the modeled benefit of mitigation measures. The “standard” height of 4 m above ground used for noise mapping purposes should thus be taken only as a reference value useful for reasons of consistency. For action plans, local situations should be carefully studied, considering the real height of all noise sensitive receivers. It is therefore recommended to divert from the default height of 4 m if this seems necessary for the specific situation under investigation. Often a set of receiver heights is appropriate to model the floor levels with residential or other "acoustically sensitive" use.

VIII.3.2.2. Yearly averaged exposure

For noise mapping, the only parameters of interest are the yearly averaged exposure levels L_{den} and L_{night} . In some cases, this choice may not be the most appropriate for the purpose of action planning. An example of such a case is a city with a large seasonal variation in the number of inhabitants. This is a quite common phenomenon in many Southern European regions with a pronounced holiday season, where touristic periods may cover up to half of the year. Here, extended operation of noisy entertainment (bars and discos), excessive road traffic (with a notable motorcycle component) are not representative of the yearly averaged exposure since during the rest of the year mobility and touristic activity are practically absent, with a corresponding significant reduction of the population and noise emissions.

As the environmental noise emissions vary with season in sync with the population the difference between the seasonally averaged and the yearly averaged exposure can be substantial. In these areas, the time period and population share should therefore be chosen to meet the goal of the local action planning. An appropriate choice for the averaging interval could be the core period of the holiday season, e.g. the 6 months from May through October for the southernmost areas of Europe and the three months from June through August for the northernmost areas. The appropriate population to be assigned should be both the permanent local inhabitants as well as the “long term” non-permanent (holiday) residents for this time period but excluding "short term" tourists even though their activities may contribute to the local acoustical climate.

The above shows quite clearly that a detailed knowledge of the specific local situation subject to an action plan is required so as to choose the adequate time period of assessment for which the noise exposure is averaged for the optimal correlation with annoyance.

VIII.3.2.3. Equal distribution

For noise mapping, the receiver points are equally distributed around the circumference of buildings as prescribed in detail in Chapter VIII.2.2. In most situations, such an equal distribution is also suitable for action planning.

In specific situations, though, the action planning team may choose to specify receiver points not equally distributed around the building, namely where noise sensitive and non-sensitive uses co-exist in the same building or where different urban formations are present. In general, diverting from the equal distribution scheme requires detailed knowledge of the floor plan of the building such that the location of individual apartments (dwelling units) inside the building can be taken into account.

This information may be available on a floor-by-floor or unit-by-unit basis. And possibly even the type of use of individual rooms and the real occupancy may be known and considered. Care should be taken not to base the decision on mitigation measures on parameters that might change significantly over the lifetime of the measure. This applies particularly to current occupancy and type of use of rooms instead of typical occupancy and designated type of use of rooms.

Diverting from the equal distribution scheme is appropriate in special situations only where detailed information about floor plans has been collected for all buildings in the focus of an action plan.

VIII.3.2.4. Buildings other than residential buildings

For noise mapping purposes, the residential population is in the focus. While information on schools and hospitals may also be depicted in strategic noise maps and reported to the European Commission, such information is not mandatory. However, secondary or vacation residences as well as schools, hospitals and other buildings with noise sensitive but non-residential use may be important within the scope of the action plan. In this case, it is necessary to introduce receiver points on the facades of these buildings.

Generally, the method that is part of the equal distribution scheme of Chapter VIII.2 may be used for this task. More difficult is the task of assigning population to receiver points in schools or hospitals as there is no residential use.

People either work/study in the building or spend a hopefully short period of time there in the case of hospitals. It depends on the specific goal of the action plan which way of assigning people to the receiver points is most appropriate. In some cases, e.g. when the purpose is to ensure compliance with exposure or noise limits, there may even be no need at all for assigning people to the receiver points.

For buildings without residential use, the equal distribution scheme cannot be readily applied for lack of inhabitants in the classical sense. It depends on the goal of the specific local action plan whether people need to be assigned to receiver points at all, and if so which methodology for this assignment is the most appropriate.

VIII.3.3. Summary

The consistency of noise maps requires a strictly standardized methodology for the assignment of the population to receiver points at the facades of buildings. In contrast, for local action

planning it is necessary to take into account specific details of the situation under consideration.

Different noise sensitive uses other than residential, buildings with sensitive and non-sensitive uses and seasonal differences implying short term averages may all be taken into account.

The most appropriate methodology will depend on the goal of the local action plan and may differ widely from case to case.

Appendix VIII-A: END Reference

VIII-A.1. Person (s)

Article 2 Scope, 2: “the exposed person himself”

Article 3 Definitions, (k) “agglomeration”: “a population in excess of 100 000 persons”

Article 3 Definitions, (v) “the public”: “one or more natural or legal persons and, in accordance with national legislation or practice, their associations, organisations or groups”

Article 11 Review and Reporting, 2 (a): “the reduction of the number of persons harmfully affected by environmental noise”

Annex VI, 1.5: “how many persons in the above categories live in dwellings that have”

Annex VI, 1.6: “how many persons in the above categories live in dwellings that have”

Annex VI, 2.5: “how many persons in the above categories live in dwellings that have”

Annex VI, 2.6: “how many persons in the above categories live in dwellings that have”

VIII-A.2. People

Article 3 Definitions, (q) “noise mapping”: “the number of people affected in a certain area”

Article 11 Review and Reporting, 4: “the lower limit for the estimated number of people exposed to different bands of L_{den} and L_{night} in Annex VI.”

Annex IV, 1: “the estimated number of people located in an area exposed to noise.”

Annex V, 1: “an evaluation of the estimated number of people exposed to noise”

Annex V, 3: “the number of people affected (annoyed, sleep disturbed, or other)”

Annex VI, 1.5: “The estimated number of people (in hundreds) living in dwellings”

Annex VI, 1.6: “The estimated total number of people (in hundreds) living in dwellings”

Annex VI, 2.5: “The estimated total number of people (in hundreds) living outside agglomerations in dwellings”

Annex VI, 2.6: “The estimated total number of people (in hundreds) living outside agglomerations in dwellings”

Annex VI, 2.7: “the estimated total number of people (in hundreds) living in each of these areas”

VIII-A.3. Population

Article 3 Definitions, (k) “agglomeration”: “a population in excess of 100 000 persons and a population density such that”

Article 3 Definitions, (s) “limit value”: “different noise sensitiveness of the populations”

Annex III: “the effect of noise on populations” and “vulnerable groups of the population”

VIII-A.4 Dwelling

Article 3 Definitions, (q) “noise mapping”: “the number of dwellings exposed to certain values of a noise indicator in a certain area”

Annex VI, 1.5: “The estimated number of people (in hundreds) living in dwellings”

Annex VI, 1.6: “The estimated total number of people (in hundreds) living in dwellings”

Annex VI, 2.5: “The estimated total number of people (in hundreds) living outside agglomerations in dwellings”

Annex VI, 2.6: “The estimated total number of people (in hundreds) living outside agglomerations in dwellings”

Annex VI, 2.7: “The estimated total number of dwellings (in hundreds)”

VIII-A.5 Building

Article 2, 1: “noise-sensitive buildings”

Annex I, 1: “noise exposure in and near buildings”

Annex VI, 1.5: “special insulation of a building”

VIII-A.6 Façade / Most exposed façade / Quiet façade

Annex I, 1: “the façade of the dwelling under consideration”

Annex I, 1: “the most exposed façade; for this purpose, the most exposed façade will be the external wall facing onto and nearest to the specific noise source; for other purposes other choices may be made”

Annex II, 2: “the façade reflection”

Annex II, 3: “in front of a façade” and “this façade or element”

Annex III: “dwellings with a quiet façade as defined in Annex VI”

Annex VI, 1.5: “the most exposed façade”

Annex VI, 1.5: “a quiet façade, meaning the façade of a dwelling at which the value of L_{den} four metres above the ground and two metres in front of the façade, for the noise emitted from a specific source, is more than 20 dB lower than at the façade having the highest value of L_{den} .”

Annex VI, 1.6: “the most exposed façade”

Annex VI, 1.6: “a quiet façade, as defined in paragraph 1.5.”

Annex VI, 2.5: “the most exposed façade” and “a quiet façade, as defined in paragraph 1.5.”

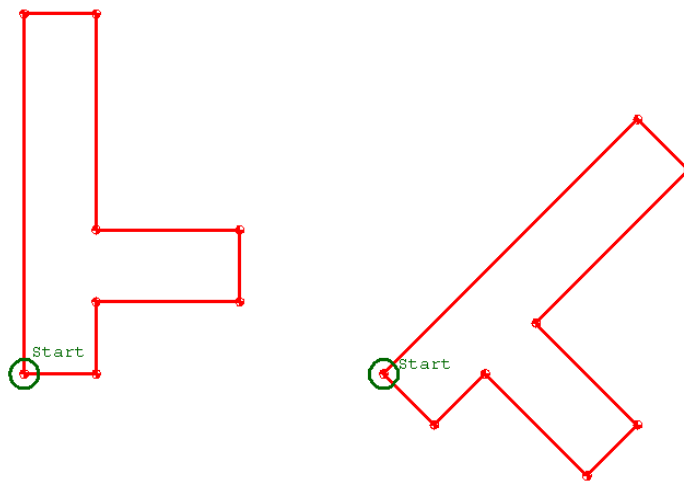
Annex VI, 2.6: “the most exposed façade” and “a quiet façade, as defined in paragraph 1.5.”

Appendix VIII-B: Demands on methodology of positioning façade receiver points

There are a couple of aspects which should be regulated by the chosen methodology for façade receiver point positioning:

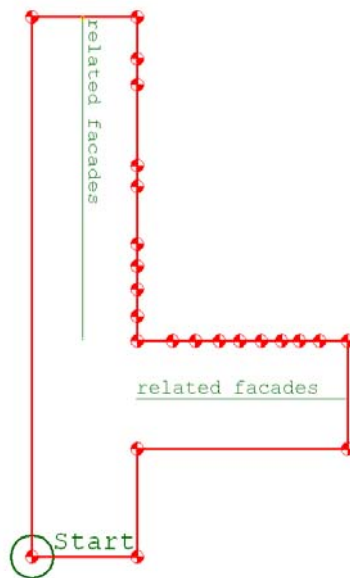
1. Façade points positions very next to the corner of a building should be avoided as they are not representative due to significant changes in the acoustical propagation near the to the building edge. As a kind of “wage” argument façade points shall represent the “architectural visual impression” of a building, i.e. should best be linked to realistic window positions for typical residential building shapes.
2. The practical distance to the façade for a receiver position “on the faced” needs to be defined, as a position “on the façade” is difficult to implement in noise mapping software.
3. The height of a façade receiver position is described in the directive as “4 m above terrain”. This is understood as terrain height at receiver position.
4. For analysis of the “quiet façade” the receiver position shall be kept at 2 m in front of the façade as already suggested in the directive.
5. No façade noise levels should be taken into account for receiver positions which are placed inside other buildings. There is such a risk if a software does not treat receiver positions inside buildings separately, but just “knocks off” the building in order to create a “dummy” receiver level.
6. In addition to the aspect above façade noise level statistics will be more in line with population experiences when they are not positioned on facades which are confronted at too short distance by any opposite façade, e.g. of a neighbouring building.
7. Two separate façades of identical length and same noise exposure shall have similar statistical impact, independent of the fact that they are either digitized as a long straight segment or a sequence of short segments.
8. Reproducibility of receiver positioning by different software packages should be achievable. The methodology may aim at different target levels and by this be of different complexity. In the order of increasing complexity of the methodology the levels of unambiguous façade point positioning might be:
 - a. Building with identical plan view shape, perhaps in rotated position, and with identical segment length for each corresponding façade segment of the compared buildings.

Each of the compared buildings will have its starting vertex in a similar position within its shape.



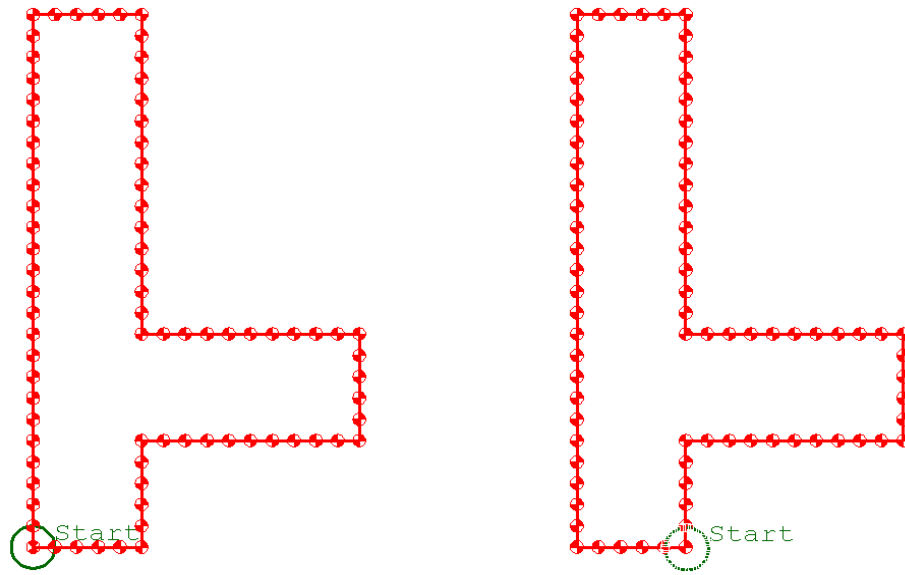
- b. Building with identical plan view shape, perhaps in rotated position, but with façade segment length varying for corresponding façade segments of the compared buildings.

Each of the compared buildings will have its starting vertex in a similar position within its shape.



- c. Building with identical plan view shape, perhaps in rotated position, but with façade segment length varying for corresponding façade segments of the compared buildings. The starting vertexes of the compared buildings do not match in their position within the building shape.

This is a useful requirement when similar buildings with identical number of inhabitants and in identical ambient noise conditions need to result in the same statistical impact. The requirement is not need to ensure reproducibility of software results, as long as the starting vertex of a building object is not modified.



Three segments build up to a required minimum length of at least 5 m, as required in German VBEB. On the right, the starting position is replaced after 5 segments, thus representative façade receiver points will not be identical any more.

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CHAPTER IX. GUIDANCE ON THE COMPETENT USE OF CNOSSOS-EU

IX.1. Aim of the guidelines

Following the completion of the first round of strategic noise mapping in 2007 [1] it has become apparent that despite the use of a common approach, there have been an array of potential solutions which have led to a diversity of answers being developed [2].

Paragraph 7 of the Directive states:

*“Data about environmental noise levels should therefore be collected, collated or reported in accordance with **comparable criteria**. This implies the use of harmonised indicators and evaluation methods, as well as **criteria for the alignment of noise-mapping**. Such criteria and methods can best be established by the Community.”*

The primary purpose of the guidelines is therefore to provide these criteria for the alignment of noise-mapping. Following a number of research studies on various aspects of strategic noise mapping, in a number of Member States, it is now widely acknowledged that there are many factors which influence the comparability of strategic noise mapping results, many outside the core process of actually calculating noise levels. Data quality and differences in agglomeration definitions, small roads in agglomerations and population assignment to buildings have all been shown to have an influence similar in magnitude to the method of assessment when determining the causes of variance between mapping projects.

- **The aim of the CNOSSOS-EU guidelines is two-fold:**
 - **To provide mandatory guidance for the application of CNOSSOS-EU for strategic noise mapping; and**
 - **To provide guidance, advice and shared best practice for the application of CNOSSOS-EU for noise action planning.**
- **The content of the CNOSSOS-EU guidelines:**
 - **Should cover the complete process of strategic noise mapping, from defining agglomerations and major sources, through to reporting results;**
 - **Should indicate the impact of differences in quality of input data;**
 - **Should provide instructions on the evaluation of emission data:**
 - **how to import national databases into CNOSSOS-EU**
 - **how to introduce new data**
 - **Should be flexible to accommodate local and regional variations (complex situations such as valley zones); and**
 - **Will need to be managed, updated and extended as necessary as application, experience and expertise in CNOSSO-EU grows in the future, potentially under**

IX.2. Target user groups

The following end users are identified as potential end users of the CNOSSOS-EU guidelines:

WHO?	NEEDS?
National authority	understand the financial costs, the complexity and the number of organisations within the MS who need to be involved within the process of implementing the directive including transposition
Competent authority	coordination, management and production of the result data of strategic noise mapping or action plans
Technical practitioner	run the project (data collection and handling, operating software, operating calculation, producing result files)
Data provider	provide the appropriate input data
Reporting coordinator at MS towards the EC	collect relevant information from the competent authorities

MS and designated bodies have a responsibility for informing the public, and public consultation, in connection with the activities under the END, and for this reason the “public” would not be seen as end users of the guidance.

There is to be a separate CNOSSOS-EU WG for software development (i.e., WG 8), and that this will feed into the guidelines. Hence, the software developers are seen as a supplier of guidance, rather than an end user.

It should be also noted that an individual, or organisation, may be in several of the user groups, depending upon the scope of their responsibilities.

IX.3. Content of the guidelines

The outline content of the guidelines was developed during the preparatory phase, and reviewed within CNOSSOS-EU WG 6. There was some discussion about meteo not being specifically mentioned, and discussion about whether the guidelines should include the output from other WGs.

The guidelines are proposed to provide a single point of reference, and as such include the outputs from other CNOSSOS-EU WGs, such as WG 10 on assigning noise levels and population to buildings, WG 9 on Electronic Noise Data Reporting Mechanism (ENDRM), and inputs from WG 1, 2, 3, 4 and 5 to provide content for the guidelines.

The following outline [Table of Contents](#) is proposed as:

- A brief **Summary Report** written to be accessible to policy and non-technical

readers, with a series of Technical Annexes

- **Outline of contents:**

1. Introduction
2. Implementing the Environmental Noise Directive
3. Application of CNOSSOS-EU
4. Overview of strategic noise mapping process
5. Areas of assessment
6. Noise calculation methods – practical experience, hints, tips, pitfalls etc
7. GIS and dataset specifications
8. Noise model datasets
9. Noise level calculations
10. Measurements
11. Post processing and analysis
12. Reporting

IX.4. Website concept

The breadth of the material covered by the outline table of contents, and the technical depth to which some of the guidance would need to be written raised concerns over the practicality of using a report format, or series of technical documents. The different needs and types of language of the various end users also led to concerns over accessibility. The issue of multi-user updating of text, with a geographically dispersed team was also raised as a potential problem.

With this challenge in mind, a website concept was developed in order to address a number of the key challenges presented by the requirements for the Guidelines. The concept aims to deliver the following benefits:

- **Multi-user authoring**
 - Enables CNOSSOS-EU WG 6 members to work simultaneously on developing multiple aspects of the guidelines
- **Instant reviewing**
 - Authored, or re-authored content is available immediately for review by the WG prior to publication
- **Managed publication**
 - An official version can be published to the user community, whilst the next version is undergoing development by the WG behind
 - Published Guidelines can be versioned and time-stamped for traceability
- **User focused content**
 - Authoring content in tiers to match each of the five identified user groups enables each type of user to access Guidelines focused towards their needs, and not be forced to go through the entire content seeking specific aspects

- **User feedback**
 - Commenting by page enables users to provide feedback on specific aspects, which in turn can improve the review and update process, whilst providing a more interactive user experience
- **Project tracking**
 - Users are able to record the use of Toolkit options, and the solutions used for typical problems. These are recorded within an XML file which may be downloaded by the user as a catalogue describing their project.
 - Users may manage multiple spate projects in this manner. By using download/upload project XML data may be shared between users, such as consultants with clients, or National competent authorities with designated bodies.
- **Search**
 - The contents of the site will be full text indexed to facilitate fast searching, and access to relevant information
- **Filtered views**
 - The “My mapping” section provides a number of pre-built filtered views through the pages of data, each matched to the type of user profile.

One of the main benefits perceived of the concept is the proposed use of the XML file underneath the website to track choices within the Level 3 Toolkits. This was initially envisaged to help practitioners understand their choices; however, it has also become clear that it may provide a number of other benefits:

- Mapping practitioner catalogues selections, datasets etc
- A “mandatory” button could pre-select the minimum requirements and provide a shopping list of all items required to meet this
- The XML file could become a method by which authorities could manage the actions of contractors, to track and report their choices
- The XML file could possibly be imported into noise mapping software to help with model setup
- Users could have multiple XML files per profile in order run or manage multiple mapping projects – possible link to Reporting Mechanism competent authorities, and reporting entities.

The “**My Mapping**” section essentially provides a filtered set of pages specifically focused on each of the identified end user groups.

Similarly, the pages which constitute “mandatory” guidance for strategic noise mapping would be date/version controlled, and a filter could provide a consolidated set of “mandatory” pages at a given date/version which would be reported back with the maps as the version used.

The guidelines website concept was adopted by the CNOSSOS-EU Technical Committee (23-24 June 2011, Bruxelles), and a proof of concept website developed by DG JRC for testing purposes.

The web pages will go through a four step process from creation to public accessibility, namely:

- **Draft** – content is being prepared by the task leader
- **Review** – content is reviewed by WG6 members for comment and feedback
- **Approval** – content is approved for publication
- **Publication** – at specific dates the publicly available pages are updated with a versioned, time stamped copy of each approved page

The CNOSSOS-EU WG 6 members will have access to a sitemap which presents the current status of each page, alongside the proposed publication schedule.

Five embedded levels of use have been defined:

- **Level 0: “Overview”**: Framework description of the method, aimed at general public and politicians
- **Level 1: “The assessment process”**: Explanations for the environmental offices and managers of the process at MS level
- **Level 2: “Description”**: General explanation of input data requirements and use of the method. Aimed at persons performing the noise mapping calculations
- **Level 3: “Toolkit”**: Exact list of inputs to be used in the calculation.
- **Level 4: “Details”**: Hints of the settings and input values, clarification of specific issues, data format tolls for National databases conversion, tools for introducing new values, use of measurements

Within each of these levels pages are group together which match the requirements at that level, as indicated by Figure IX-1.

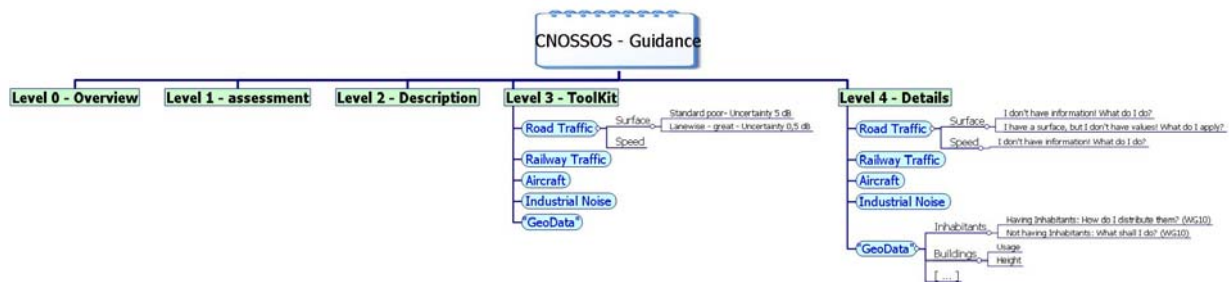


Figure IX-1: Five levels of information within the navigation structure of the Guideline

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If you chose to install the default content, you will see numerous pages available to read. You should read them thoroughly as these default pages are devoted to showing you the basics of how to begin working with CMS Made Simple. On these example pages, templates, and stylesheets many of the features of the default installation of CMS Made Simple are described and demonstrated. You can learn much about the power of CMS Made Simple by absorbing this information.

To get to the Administration Console you have to login as the administrator (with the username/password you mentioned during the installation process) on your site at <http://yourwebsite.com/cmsmspath/admin>. If this is your site click [here](#) to login.

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 - ▼ Speed
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 - ▼ Speed - DETAILS
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 - Railway noise source emission
 - Industrial noise source emission
 - Aircraft noise source emission
 - Sound propagation
 - GIS and dataset specifications
 - ▼ Noise levels calculations
 - ▼ Measurements
 - ▼ Reporting of Results
 - Public Participation
- ▼ My mapping
- F.A.Q.

Speed - TOOLKIT

Available information	Complexity	Accuracy	Cost	Use
Speed for day, evening and night	Low	<0.5 dB	Low	<input checked="" type="radio"/>
Speed for each hour of the day	Low	<0.5 dB	Medium	<input type="radio"/>
Speed for day and night	Low	<0.5 dB	High	<input type="radio"/>
Traffic speed for an 18-hour day or a full 24-hour day (or longer period of time)	Low	1 dB	High	<input type="radio"/>
Speed for weekdays	Low	<0.5 dB	High	<input type="radio"/>

Available information	Complexity	Accuracy	Cost	Use
+/-5 km/h	High	<0.5 dB	Medium	<input checked="" type="radio"/>
+/-10 km/h	Low	1 dB	Medium	<input type="radio"/>
+/-20 km/h	Low	2 dB	Low	<input type="radio"/>

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Level 4

Speed - DETAILS

General discussion

It will generally be impractical for Member States to make traffic flow, composition and speed measurements for all the roads covered by the END. Therefore, it is likely that most Member States will use traffic models as the basis of obtaining a lot of this data for strategic noise mapping purposes (especially for agglomerations). These models often only provide peak hour flow and composition data and journey time speeds. Such data cannot be used directly for the calculation of the Lden and Lnight indicators and, therefore, need to be factored to provide long-term day, evening and night data. There are several possibilities for doing this, for example, by using the traffic data that has been measured to develop, validate or maintain a traffic model. From such measurements it may be possible to produce conversion factors for various categories of roads that can then be used to estimate the day, evening and night-time flow on these roads. Alternatively, such conversion factors could be developed from long-term flow and speed measurement studies specifically undertaken for this purpose.

Road traffic models often provide traffic speeds that are based on journey times. These speeds include the delays experienced at junctions, traffic lights etc. For strategic noise mapping, the average speed in free flowing sections of the road is generally required.

Traffic flows and speeds are frequently not readily available for every lane of multi-lane road corridors and occasionally may not even be available for each direction. Alternative ways of assigning flows and speeds in such circumstances are discussed below: Assignment by lane. Where data is available for each lane of a multi-lane corridor and this shows that there is a significant difference between the traffic data for each lane it may be appropriate to assign different data to each lane. It may be important to do this where reception points are close to the road or when the immediate surroundings of the road may have a strong influence on noise propagation (for example, where a road is in a cutting or on an embankment). Assignment by direction. This is normally necessary and particularly so when it is known that traffic data for the different directions are significantly different or when the road gradient may significantly affect the noise emission (as determined by the model being used but typically when the gradient is greater than 3%). Assignment by road. In this case a combined two-way flow is assigned to a multi-lane road (normally to the centre line of the road corridor). This is generally only acceptable for strategic assessment when the road gradient is not important (as determined by the model being used but typically when the gradient is less than 3%).

Annex IV (3) of the END indicates that noise maps for agglomerations have to place a special emphasis on road traffic. A strict interpretation of the END could mean that all roads in agglomerations have to be mapped. However, no advice is provided on how to deal with speed on low flow roads where reliable flow data is unavailable, or indeed on which low flow roads need to be mapped.

Low flow roads

Traffic flow data is unlikely to be available for every road in an agglomeration, especially for low flow roads, but the END implies that all roads have to be taken into account and mapped. In these areas there appear to be three possible solutions to this problem, which have varying degrees of associated complexity, accuracy and expense. The areas follows: 1. Obtain and use accurate traffic flow data from a traffic flow model and/or traffic counts for all roads, including low flow roads. This is the best solution. 2. Assign default flow values for roads with flows that are known to have, or are likely to have, flows that are below a certain figure per day (or per year). This solution takes account of roads, which is in accordance with the END.

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IX.5. Interim method guidelines for the 2nd round of strategic noise mapping

Throughout the two days of the CNOSSOS-EU WG 6 meeting (15-16 February 2011, Bruxelles) there were two subjects which arose regularly, namely:

- Demonstrating the website concept using a live website, with genuine content will provide a more useful means of evaluating the concept; and
- Is there a way of providing additional support to Member States (MS), Competent Authorities (CA) and designated bodies during the second round?

It was agreed that the 2nd round of mapping in 2012 is outside the scope of the CNOSSOS-EU process, however there are other CNOSSOS-EU WGs delivering interim results proposed to be of use during the 2nd round, namely WG 9 on “Electronic Noise Data Reporting Mechanism” and WG 10 on “Assigning noise levels and population in buildings”.

Despite the clear situation, a majority of WG 6 members present argued that developing the guidelines website concept using content from WG-AEN GPGv2 [3, 4], supplemented by other known sources, could:

- provide benefit to MS, CA and designated bodies;
 - an estimated 21 of 27 MS will use the interim methods for at least one noise source;
- help to spread best practice;
- demonstrate the usability of the website concept and drive development; and
- provide a means of management and control over contractors if the XML reporting tool is developed within the website.

CNOSSOS-EU WG 6 resolved to add an objective to the terms of reference which aims to deliver an Interim Method (IM) guidance website during 2011 based upon WG-AEN GPGv2, supplemented by a number of other identified guidance and/or best practice documents, including:

- **Hepworth Acoustics DEFRA Reports NANR 93 and NANR 208 [5, 6];**
- **Imagine Reports [7];**
- **Wolfel Report on Interime noise computational methods [8];**
- **NoMEPorts Good Practice Guide [9];**
- **DIN 45687 [10];**
- **French NMPB Guidance;**
- **CNOSSOS-EU WG 10 results on assigning people and noise levels to**

buildings (se chapter VIII of present report); and

- **Revised EEA Electronic Noise Data Reporting Mechanism.**

The following timetable was agreed for the development of the Interim Method (IM) Guidelines:

- **30/08/11 - First draft IM Guidelines website with GPGv2 content;**
- **17/10/11 - Second draft IM Guidelines website with GPGv2 content plus other identified Best Practice;**
- **30/12/11 - Final Draft IM Guidelines website with GPGv2 content plus other identified Best Practice, additionally including the interim results proposed to be of use during 2nd round delivered from WG10 "Assigning noise levels and population in buildings" and WG9 "Data reporting mechanism; and**
- **01/02/12 - Final IM Guidelines website with WG-AEN v2 and additional content.**

IX.6. Roadmap for guidelines

The development of full content for the guidelines is dependent upon a number of other aspects of the CNOSSOS-EU process, including: finalising the methodology; developing a software tool; testing and fine-tuning the methodology; validation testing; error propagation and uncertainty analysis; and real world user experience.

It was quickly realised that the first phase of work on the guidelines could only deliver the framework for the content and delivery method, whilst the main content would need to be developed in parallel to the subsequent stages of the CNOSSOS-EU process. This led to a roadmap for the development of the guidelines in stages.

- **Structure and content of Interim Method Guidelines to be developed and completed by October 2011;**
- **Structure of the CNOSSOS-EU guidance should be worked out and agreed by October 2011;**
- **Content of the mandatory CNOSSOS-EU guidance for strategic noise mapping is to be developed after the CNOSSOS-EU method is fixed, i.e. beginning November 2011, with an aim to finish the first version by October 2012;**
- **Content of the optional CNOSSOS-EU guidance for noise action planning, with an aim to finish the first version by October 2013.**

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CHAPTER X. REVISED ELECTRONIC NOISE DATA REPORTING MECHANISM

The chapter on the “Revised Electronic Noise Data Reporting Mechanism” is under preparation by the CNOSSOS-EU WG 9 co-ordinated by the European Environment Agency (EEA) and will be incorporated into the final version of the present report by November/December 2011.

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Abstract

In accordance with Art. 6.2 of the Environmental Noise Directive 2002/49/EC (END), the European Commission developed Common NOise aSSessment methOdS (CNOSSOS-EU) for road, railway, aircraft and industrial noise to be used after adoption by the Member States for the purpose of strategic noise mapping as required by Article 7 of the END. The development of CNOSSOS-EU was co-ordinated by the Joint Research Centre's Institute of Health and Consumer Protection and performed in close liaison with the CNOSSOS-EU Technical Committee which was composed from experts nominated by the Member States and setup under the Regulatory Noise Committee. The overall work was performed in the context of two consecutive administrative arrangements stipulated between the Joint Research Centre and the Directorate General for Environment (DG ENV), namely NOISE-II (contract no. 070307/2008/511090) and NOISE-III (contract no. 070307/2009/549280).

This report forms the basis for amending Annex II of Directive 2002/49/EC of the European Parliament and of the Council relating to the assessment and management of environmental noise in Europe. CNOSSOS-EU aims at improving the reliability and comparability of noise assessment results across the EU Member States which are performed on the basis of the data becoming available through the consecutive rounds of noise mapping in Europe.

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