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Common Noise Assessment Methods in Europe (CNOSSOS-EU)

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

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For providing

Technical advice to DG ENV related to the preparation and implementation of the Common Noise Assessment methods in Europe (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 the technical basis for the European 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 short

This report describes CNOSSOS-EU, the common methodological framework for strategic noise mapping under the Environmental Noise Directive (2002/49/EC). It also outlines the process and the key actors involved in the development of CNOSSOS-EU. The report closes the development phase of the CNOSSOS-EU process (2010-2012) and represents the technical basis for the amendment of Annex II of the Directive, in connection with the implementation phase of CNOSSOS-EU (2012-2015). The ultimate goal is to have the common noise assessment methodology operational for the next round of strategic noise mapping in the European Union, foreseen for 2017.

Context

Europe is acting to fight noise pollution. The Environmental Noise Directive (2002/49/EC) requires EU Member States to determine the exposure to environmental noise through strategic noise mapping and elaborate action plans to reduce noise pollution. Since June 2007, EU countries are obliged to produce strategic noise maps for all major roads, railways, airports and agglomerations, on a five-year basis. These noise maps are used by national competent authorities to identify priorities for action planning and by the European Commission to globally assess noise exposure across the EU. This information also serves to inform the general public about the levels of noise to which they are exposed, and about actions undertaken to reduce noise pollution to a level not harmful to public health and the environment.

A common harmonised framework for noise assessment

A common approach for assessing noise levels in Europe is an important prerequisite for improving the effectiveness of implementing the Environmental Noise Directive. This will help in obtaining consistent and comparable figures on the number of people exposed to noise levels in and across EU Member States. To achieve this, Article 6.2 of the Directive foresees the development of a harmonised methodological framework for noise assessment. In 2009, the European Commission decided to develop CNOSSOS-EU (Common NOise aSSessment MethOdS) for noise mapping of road traffic, railway traffic, aircraft and industrial noise.

The present report describes this methodological framework, which was developed in the development phase (phase A) of the CNOSSOS-EU process to be applied for strategic noise mapping in Europe. It was based on state-of-the-art scientific, technical and practical knowledge about environmental noise assessment in Europe, while considering the cost burden incurred by EU countries when undertaking the periodic strategic noise mapping.

The core of the CNOSSOS-EU methodological framework consists of:

- a quality framework that describes the objectives and requirements of CNOSSOS-EU;
- parts describing road traffic, railway traffic, industrial noise source emission and sound propagation;

- a part describing the methodology chosen for the aircraft noise prediction and its associated performance database;
- a methodology to assign receiver points to the façades of buildings and to assign population data to the receiver points at the façades of buildings;
- the scope and the concept of the "Guidance for the competent use of CNOSSOS-EU", which should be fully developed in the implementation phase (phase B) of the CNOSSOS-EU process.

Moreover, a summary on the outcome of the revision of the Electronic Noise Data Reporting Mechanism, which was led by the European Environment Agency, is also included in the present report as it represents the key interface between the noise assessment throughout Europe and the sharing of the results by means of one common noise methodological framework.

CNOSSOS-EU was developed during the period 2009-2012 by the European Commission in a cooperative process involving the European Environmental Agency, the World Health Organization Europe, the European Aviation Safety Agency and experts nominated by EU countries. Besides the development of the common noise methodological framework, the CNOSSOS-EU process has also fostered dialogue between the stakeholders involved, and enabled them to liaise and perform their activities synergistically under a joint collaborative framework to face the challenges ahead:

- Make available to European citizens reliable information 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 in a sustainable and resource-efficient way.

The readers of the present report are encouraged to also consult its companion JRC Master Report[1], as this latter report provides the justification basis for the choices made about the various parts of the CNOSSOS-EU methodological framework for strategic noise mapping.

The way forward

Based on this report, the European Commission will amend Annex II of Directive 2002/49/EC, in connection with the implementation phase of CNOSSOS-EU (phase B) in 2012-2015. The ultimate goal is to have the common noise assessment methodology operational for the next round of strategic noise mapping in the European Union, in 2017.

During phase B, the CNOSSOS-EU methodological framework will be extended to allow its application by EU Member States on a voluntary basis for other specific types of assessment at local scale (e.g. action planning). For the latter, the precision and accuracy requirements of the assessment are usually higher to those when producing strategic noise maps as required by Directive 2002/49/EC (mandatory requirement) in which case economically affordable solutions (i.e. related to input data gathering and computational time) are sought by eventually reducing the requirements of precision and accuracy.

[1] JRC Master Report on "Common Noise Assessment Methods in Europe (CNOSSOS-EU): Outcome and Resolutions of the CNOSSOS-EU Technical Committee & Working Groups" (2012)

ACKNOWLEDGEMENTS

Special recognition goes to the experts of the CNOSSOS-EU Technical Committee (nominated by the Member States and set up under the Noise Regulatory Committee) for providing their advice on a continuous basis throughout the development of the CNOSSOS-EU methodological framework for strategic noise mapping and also 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 presenting the Member States' experiences 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 and its efficient and economically affordable implementation in Europe.

The contribution received from the wide array of noise experts involved during the preparatory stage of the CNOSSOS-EU development is greatly appreciated as it paved the way for the further development of CNOSSOS-EU, which has been carried out since November 2010 under formal consultation with EU Member States.

The dedicated efforts by the European Environment Agency (EEA) and the World Health Organization (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 the Directorate-General for the Environment (DG ENV) and Directorate-General Joint Research Centre (DG JRC) are highly appreciated.

Last but not least, DG ENV (Directorate C "Sustainable Resources Management, Industry & Air") and DG JRC (Directorate I "Institute for Health and Consumer Protection") are gratefully acknowledged for having financially supported the CNOSSOS-EU development.

CHAPTER I. INTRODUCTION

I.1. Background and objectives of this report

I.1.1. CNOSSOS-EU in relation to the Noise Directive 2002/49/EC

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 (MS) produce strategic noise maps for all major roads, railways, airports and agglomerations pursuant to Article 7 (1), starting as from 30 June 2007 on a five-year basis. Strategic noise maps are to be used by the Competent Authorities (CA) in the EU MS to identify priorities for action planning and by the Commission to assess the number of people exposed to noise. This information will also serve to inform the general public about the levels of noise to which they are exposed and the actions which are undertaken to reduce this exposure to noise levels that are not harmful for 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, namely the day-evening-night level L_{den} and the night level L_{night}, and strategic noise maps are being produced by EU MS 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 European Commission to establish common assessment methods for the determination of the noise indicators L_{den} and L_{night}. Until these methods are adopted, MS may use assessment methods adapted in accordance with Annex II of the END and based on the methods laid down in EU MS 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 during the first round of strategic noise mapping (2006-2007) and established that the assessment methods laid down in the national transposing measures differ significantly from the interim methods.[2] Assessments have shown that it remains difficult to present consistent and comparable figures on the number of people being exposed to excessive noise levels within and across EU MS. Difficulties relate, *inter alia*, to the different ways of collecting data, data quality and availability, data reporting and the assessment methods used.[3]

Consequently, in accordance with Article 6.2 of the Environmental Noise Directive 2002/49/EC (END), the Commission undertook the development of **C**ommon **NO**ise a**SS**essment meth**O**d**S** (**CNOSSOS-EU**) for *road traffic*, *railway traffic*, *aircraft* and *industrial* noise to be applied after adoption by MS for strategic noise mapping as required by the END.

[2] DG JRC report on "Assessment of the equivalence of national noise mapping methods against the interim methods" prepared in the context of the NOISE-I administrative arrangement between DG ENV and DG JRC (contract no 07-0303/2007/477794/MAR/C3)

[3] Report from the Commission to the European Parliament and the Council on the implementation of the Environmental Noise Directive in accordance with Article 11 of the Directive 2002/49/EC, COM(2011) 321 final, Brussels, 1.6.2011

The development of CNOSSOS-EU was co-ordinated by the Directorate-General for the Joint Research Centre (DG JRC) on behalf of the Directorate-General for the Environment (DG ENV) and was accomplished in the context of two consecutive administrative arrangements stipulated between DG ENV and DG JRC, namely NOISE-II (contract no 070307/2008/511090) and NOISE-III (contract no 070307/2009/549280).

The Commission's objective is to have CNOSSOS-EU implemented and operational in EU MS starting from the third round of strategic noise mapping in 2017.

I.1.2. The CNOSSOS-EU process

The development of the CNOSSOS-EU methodological framework was the fruit of an intensive and in-depth consultation which involved European Commission services, EEA, EASA, WHO-Europe and nearly 150 noise experts in two consecutive stages (Figure I.1). During an initial informal stage (March 2009 to May 2010), the ground was prepared for the formal consultation and the technical developments that were undertaken with MS during the second stage of the project (November 2010 to March 2012). This latter stage involved the CNOSSOS-EU Technical Committee, which was composed of experts nominated by MS and set up in November 2010 under the Noise Regulatory Committee (NRC), which is chaired by the DG ENV.

Figure I.1: *Experts involved in the CNOSSOS-EU process*

The CNOSSOS-EU Technical Committee and its associated working groups/drafting teams (WGs/DTs) were involved in the technical development of the CNOSSOS-EU methodological framework and acted as the review panel of the content of this report.

The second and formal stage of the CNOSSOS-EU process is schematically presented in Figure I.2.

Figure I.2: *The steps of the second and formal stage of the CNOSSOS-EU process*

I.1.3. The JRC Reference Report on CNOSSOS-EU

This JRC Reference Report describes the core common noise assessment methodological framework (CNOSSOS-EU) developed for strategic noise mapping in phase A of the CNOSSOS-EU process, which is compatible with the 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 phase A of the CNOSSOS-EU process, eight out of the thirteen WGs/DTs of the CNOSSOS-EU Technical Committee were activated (Figure I.3). This led to the CNOSSOS-EU methodological framework, which is described in the various chapters of this report, namely:

- WG 1 on "Quality Framework"

  Described the objective and the requirements of CNOSSOS-EU (Chapter II)

- WG 2 on "Road traffic noise source emission"

  Described the road traffic noise source emission part of CNOSSOS-EU and its associated parameters, along with methodological aspects for establishing a database of input values for road traffic noise (Chapter III)

- WG 3 on "Railway traffic noise source emission"

  Described the railway traffic noise source emission part of CNOSSOS-EU and its associated parameters, along with methodological aspects for establishing a database of input values for railway traffic noise (Chapter IV)

- WG 4 on "Aircraft noise prediction"

  Described the component of CNOSSOS-EU related to aircraft noise prediction and its associated performance database (Chapter VII)

- WG 5 "Sound propagation and industrial noise source emission"

  Described the industrial noise source emission and the sound propagation parts of

CNOSSOS-EU (Chapters V and VI respectively)

- WG 6 “Good practice guidelines”

  Developed the scope and conceptualised the structure and content of the “Guidance for the competent use of CNOSSOS-EU”, which should be fully developed in phase B of the CNOSSOS-EU process (Chapter IX)

- WG 9 on “Revised Electronic Noise Data Reporting Mechanism” (ENDRM)

  Reviewed the Electronic Noise Data Reporting Mechanism, which was co-ordinated by the EEA and represents the key interface between noise assessment throughout Europe and the sharing of results by means of one common noise methodological framework (Chapter X)

- WG 10 on “Assigning noise levels and population to buildings”

  Developed the methodology to assign receiver points to the façades of buildings, and to assign population data to the receiver points at the façades of buildings (Chapter VIII).

The outcome of the work performed by the aforementioned eight WGs/DTs (excluding that of WG/DT 9) constitutes the core part of the CNOSSOS-EU methodological framework, which will provide the technical basis for the legal text of the Implementing Act related to the amendment of Annex II of Directive 2002/49/EC.

The issues tackled and resolutions made by the WGs/DTs activated in phase A of CNOSSOS-EU are described in the JRC Master Report on CNOSSOS-EU.[4] The readers of the present report are encouraged to also consult the Master Report on CNOSSOS-EU as this provides the justification for the choices made about the various parts of the CNOSSOS-EU methodological framework for strategic noise mapping.

Four other WGs (plus WG/DT 6 on “Good practice guidelines”) pertain to the implementation phase of CNOSSOS-EU (2012-2015) in EU MS (phase B), namely:

- WG 7 on “CNOSSOS-EU database”

  To set up the CNOSSOS-EU database of input data for road traffic, railway traffic, industrial and aircraft noise and to develop the procedure to be used for transposing national databases into the CNOSSOS-EU database

- WG 8 on “CNOSSOS-EU reference software”

  To develop the CNOSSOS-EU reference software for road traffic, railway traffic, industrial noise source emission and point-to-point propagation calculations and for aircraft noise prediction

- WG 12 on “Pilot studies for CNOSSOS-EU validation”

  To develop test cases and pilot studies for various meteorological and ground configurations (e.g., specific meteorological conditions, particular cross-sections like valleys/hills, small barriers, street canyons, lateral diffraction around obstacles, etc.) to validate the CNOSSOS-EU methodological framework in terms of precision, accuracy and computational time when applied for strategic noise mapping

[4] JRC Master Report on “Common Noise Assessment Methods in Europe (CNOSSOS-EU): Outcome and Resolutions of the CNOSSOS-EU Technical Committee & Working Groups” (2012)

- WG 13 on "Help desk and Training for EU MS"

  To provide EU MS with help desk and training on the competent use of the CNOSSOS-EU methodological framework for strategic noise mapping.

PHASE A

CNOSSOS-EU WG/DT 1	"Quality framework"
CNOSSOS-EU WG/DT 2	"Road traffic noise source emission"
CNOSSOS-EU WG/DT 3	"Railway traffic noise source emission"
CNOSSOS-EU WG/DT 4	"Aircraft noise prediction"
CNOSSOS-EU WG/DT 5	"Sound propagation and industrial noise source emission"
CNOSSOS-EU WG/DT 6	"Good practice guidelines"
CNOSSOS-EU WG/DT 9	"Revised Electronic Noise Data Reporting Mechanism"
CNOSSOS-EU WG/DT 10	"Assigning noise levels and population to buildings"

PHASE B

CNOSSOS-EU WG/DT 6	"Good practice guidelines"
CNOSSOS-EU WG/DT 7	"CNOSSOS-EU database"
CNOSSOS-EU WG/DT 8	"CNOSSOS-EU reference software"
CNOSSOS-EU WG/DT 11	"Burden of disease estimation"
CNOSSOS-EU WG/DT 12	"Pilot studies for CNOSSOS-EU validation"
CNOSSOS-EU WG/DT 13	"Help desk and training for EU MS"

Figure I.3: *CNOSSOS-EU working groups/drafting teams*

One additional working group (WG 11) was considered for directly liaising with the on-going activities on "Burden of disease estimation", which are co-ordinated by the WHO-European

Centre for Environment and Health. This serves the purpose of helping the evaluation of the burden of disease due to environmental noise by using the noise exposure data gathered in the context of the periodic rounds of strategic noise mapping in Europe.

The overall organisational structure of the CNOSSOS-EU Technical Committee and its associated WGs/DTs in both phases of the second and formal stage of the CNOSSOS-EU process is shown in Figure I.3.

The outcome of all meetings and workshops which were organised in both stages of the CNOSSOS-EU development may be retrieved via the CIRCA website of DG ENV (http://circa.europa.eu/Public/irc/env/noisedir/library).

As CNOSSOS-EU has been designed to make cost-efficient calculations of A-weighted outdoor sound pressure levels for strategic noise maps, it is not necessarily the optimum method for other purposes. During Phase B of the CNOSSOS-EU process, which will focus on the implementation of the CNOSSOS-EU tools and validation (2012-2015), the CNOSSOS-EU methodological framework will be extended to allow its application by EU MS on a voluntary basis for other specific types of assessment at local scale (e.g. action planning). For the latter, the precision and accuracy requirements of the assessment are usually higher to those when producing strategic noise maps as required by Directive 2002/49/EC (mandatory requirement) in which case economically affordable solutions (i.e. related to input data gathering and computational time) are sought by eventually reducing the requirements of precision and accuracy.

The present report describes the core of the CNOSSOS-EU methodological framework for strategic noise mapping. However, it does not include the input values and databases to be used for the practical application of CNOSSOS-EU throughout Europe, or the CNOSSOS-EU reference software, both of which will be developed in phase B of the CNOSSOS-EU process (DT/WG 7 and DT/WG 8). It should be underlined that CNOSSOS-EU does not aim to cover the full range of existing national and regional circumstances. However, in the CNOSSOS-EU "Good practice guidelines" to be developed by CNOSSOS-EU WG/DT 6 during phase B of the CNOSSOS-EU process, ways to consider and introduce national or regional data will be described, for example particular road surface types or vehicle types used in some MS. Moreover, a methodology for adapting national databases of input values to the CNOSSOS-EU database will also be developed, thus ensuring a smooth transition from existing national methods to CNOSSOS-EU.

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

I.2. Definitions and symbols

I.2.1. General concepts

Point source

A point source is an elementary dimensionless representation of an ideal source of noise located in a specific place in space. Point source strength is expressed exclusively by the directional 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 the definition of 'sound power' in this chapter.

Source line/source line segment

A source line[5] is an approximate trajectory of a moving equivalent point source or a series of point sources along the line in the case of fixed sources, all point sources being mutually incoherent. For practical reasons, a source line can be approximated by a set of straight-line segments (polyline). However, ideally, it would be represented by a curve in space.

A source line is characterised by a continuous distribution of point sources. The strength of a source line is expressed as directional sound power level per metre per frequency band, towards a specific direction in 3D 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. Point sources are situated at the intersections of each propagation path with each source line.

The segmentation process consists of:

- the splitting of source lines into smaller source line segments
- the replacement of the segments by equivalent point sources.

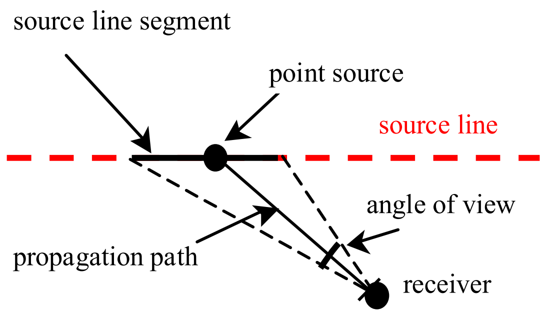

Figure I.4: *Source line, source line segment, propagation path and angle of view*

Propagation sector/angle of view

The propagation sector is an angular sector drawn from the receiver to both ends of the source line segment. The angle between the lines from the receiver to both ends of the

[5] The term 'source line' was preferred to the usual term 'line source' because the later corresponds to a line of sources pulsating with coherent phase, whereas in the present method the point sources in the line are pulsating with incoherent phase.

source line segment is called the angle of view of the propagation sector (Figure I.4).

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

Homogeneous propagation sector

A propagation sector is considered to be homogeneous if:

- the directional sound power of the source is almost constant over the source line segment
- the excess propagation attenuation within the sector varies slowly with the position along the source line.

Within a homogeneous propagation sector, the source line 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.

Equivalent vehicle

An equivalent vehicle is an ideal vehicle for which the acoustically relevant properties correspond to the average of a specific set of real vehicles moving along a specific road or railway.

Vehicle model

The vehicle model is the acoustical description of a single moving equivalent 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, thus in terms of directional source sound power level.

Traffic model

The traffic model is the acoustical description of a traffic flow, based on the directional source 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.

NB: 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 receiver is 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.5.

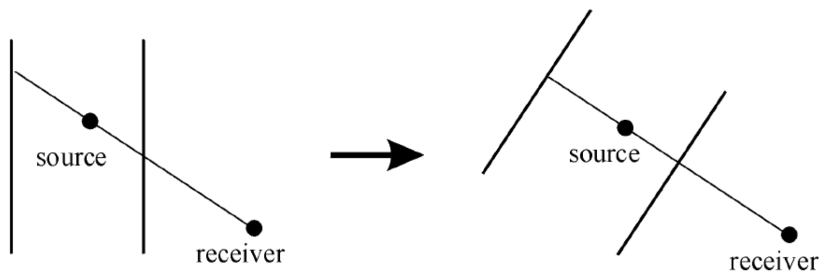

Figure I.5: *Illustration of the 2D approximation: the situation with barriers at an arbitrary angle to the source-receiver line (left) is replaced by barriers perpendicular to the source-receiver line (right)*

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 2D 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 2D 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 sources (road, railway and aircraft), such paths usually make a negligible contribution to the total sound levels and can therefore be omitted. For relatively small-sized sources (i.e. source elements that are smaller than the propagation distance), as in the case of industrial areas or tunnel openings, 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 VI. Different propagation paths, even when originating from a single point source, are always considered as incoherent.

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

- It operates on a 2.5D geometrical model, consisting of 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.

The two cases at the top of Figure I.6 have additional ray paths compared with 'regular' geometries. Advanced path detection methods are required in such cases. In the two cases at the bottom, it is more efficient to use algorithms for propagation through tunnels and for radiation from openings rather than generating numerous (higher order) reflection paths.

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

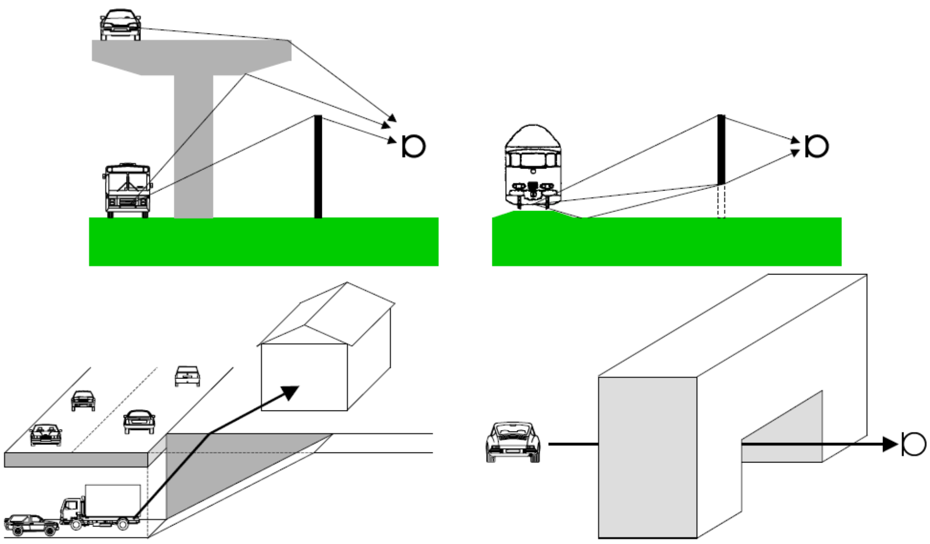

Figure I.6: *Examples of ray paths in complex geometries*

Sound power

In the CNOSSOS-EU model, the acoustical emission of all sources is defined as directional sound power level emitted per frequency band. Real sources are commonly close to reflecting surfaces that are included in the source definition as defined in ISO 9614. The sound power of the source as defined in this method includes possible effects 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 any nearby vertical surface opposite to the direction of the source-receiver. This sound power is commonly defined as 'semi-free field' or 'in situ' sound power. Any surface that has been included and counted to determine the directional source sound power level should not be used in the propagation calculation. In the following chapters, for simplicity, the word 'level' is omitted when referring to sound power levels. All sound power (levels) are defined with reference sound power W_0.

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 for instance downwind propagation (downward refraction), propagation under neutral conditions (straight propagation paths) and upwind propagation (upward refraction). Positive temperature gradients ('inversion') have similar effects (if not more pronounced) to downwind conditions.

Meteorological data

Since the definition of the ray path depends on meteorological conditions, statistical data on temperature gradients, wind speeds 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 sources. Such input data may prove too difficult to obtain, in which case associated parameters may 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 for 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 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 band definitions

The CNOSSOS-EU method is valid for determining noise in the frequency range from 125 Hz to 4 kHz for road traffic noise, from 125 Hz to 4 kHz for railway noise, from 63 Hz to 4 kHz for industrial noise and from 50 Hz to 10 kHz for aircraft noise. It provides frequency band results at the corresponding frequency interval.

Calculations are performed in octave bands for road traffic, railway traffic and industrial noise. Aircraft noise integrates all spectra into a single number (NPD data) for calculations. For road traffic, railway traffic and industrial noise, based on these 1/3 octave band results, the A-weighted sound pressure level $L_{eq,T}$ is computed by summation over all frequencies:

$$L_{eq,T} = 10 \times \lg \sum_{i=1} 10^{\left(L_{eq,T,i} + A_i\right)/10} \qquad (I\text{-}1)$$

where

A_j denotes the A-weighting correction according to IEC 61672-1

i = frequency band index.

I.2.3. Indicators

Noise indicators

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

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

where

L_{day} (respectively $L_{evening}$ and L_{night}) is the A-weighted long-term average sound level, as defined in ISO 1996-2: 2007, determined over all the day (respectively evening and night) periods of a year, and obtained on the basis of $L_{eq,T}$ as defined in Section I.2.2.

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 differently 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 following two tables.

Noise parameters:

L_p	Instantaneous sound pressure level	[dB] (re. 2 10^{-5} Pa)
$L_{Aeq,LT}$	Global long-term sound level L_{Aeq} due to all sources and image sources at point R	[dB] (re. 2 10^{-5} Pa)
L_W	*'In situ'* 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 *'in situ'* sound power level per metre of source line	[dB] (re. 10^{-12} W)

Other physical parameters:

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

CHAPTER II. QUALITY FRAMEWORK

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 MS to fulfil their obligations under the END.

II.2 CNOSSOS-EU requirements

1. CNOSSOS-EU should be designed to produce plausible noise maps showing plausible results.
2. The precise sources/scope to be included in the strategic noise mapping should be defined. In doing so, the burden imposed by including a certain source should be balanced against the noise impact of that source:
    a. For road transport, define exactly which roads should be included in the road noise mapping of an agglomeration;
    b. For rail transport, define exactly which railways, trams and light rail systems should be included in the railway noise mapping of an agglomeration;
    c. For industry, define exactly the industry types to be included in the agglomerations;
    d. For air transport, define the precise airports that should be mapped, in particular in relation to non-major airports affecting agglomerations;
    e. For agglomerations, define exactly what an agglomeration is for the purposes of strategic noise mapping.

    It is recognised that as the definition of an agglomeration is part of the END text, this cannot be changed as part of these requirements.
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 CNOSSOS-EU WGs on noise emission sources should identify the essential input parameters. For the purposes of CNOSSOS-EU, a parameter is considered essential if the range of values the parameter can take yields variations in L_{den} or L_{night} 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 CNOSSOS-EU, the input data for the essential parameters should reflect the actual usage and there should be no reliance on default input values.
5. Taking into account the requirement of (3) above, the accuracy required from the essential input data should be defined by the CNOSSOS-EU WGs on noise emission sources.
6. For aircraft noise, a precise definition is required for the source information to be used for airport noise mapping, in particular in relation to flight profiles, dispersion and other operational conditions, etc.
7. The conditions for including information in the model about obstacles on the propagation path

should be defined.

8. The method for carrying out exposure assessments should be defined precisely and designed to meet the requirement of (1) above. This applies equally to dwelling exposure, area exposure and population exposure.
9. In all their decision-making, the CNOSSOS-EU WGs on noise emission sources should take into account the cost to MS of obtaining the input data required and of undertaking the periodic strategic noise mapping. This applies especially to the definition of sources to be included in (2) above, to the definition of the essential parameters in (3) above and to the specification of requirements on input data quality in (5) above.
10. Requirements for Quality Compliance shall be recommended to the MS concerning the production and reporting of strategic noise maps to the Commission.

Points 2 (a), (b), (c) and (d) mentioned above are recognised to be critical requirements, important for the consistency of the strategic noise mapping results (i.e. the estimation of the overall population exposed at specific noise levels in an agglomeration) and needs to be specified. The aforementioned requirements cannot be developed in detail during Phase A of the CNOSSOS-EU development, as they have policy, legal and cost implications which are not yet sufficiently explored.

CHAPTER III. ROAD TRAFFIC NOISE SOURCE EMISSION

III.1. Source description

III.1.1. Classification of vehicles

The road traffic noise source is determined by combining the noise emission of each individual vehicle forming the traffic flow. These vehicles are grouped into four separate 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 numbers usually vary widely.

A fifth category is foreseen as an open class for new vehicles that may be developed in the future and may be 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.

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

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, SUVs[2], MPVs[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 future needs		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

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 (category 1, 2, 3 and 4) is represented by one single point source. As depicted in Figure III.1, this point source is placed 0.05 m above the road surface.

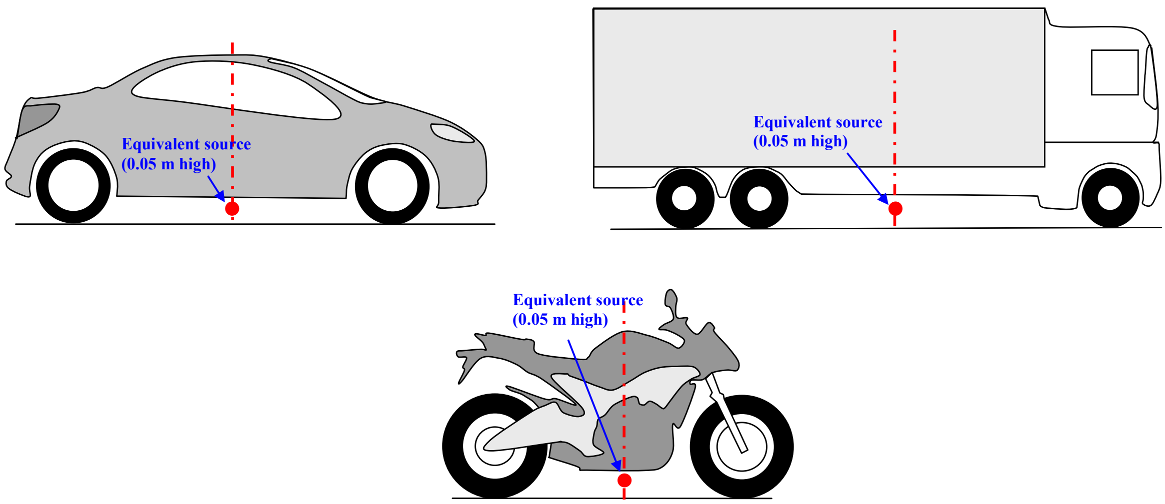

Figure III.1: *Location of equivalent point source on light vehicles (category 1), heavy vehicles (categories 2 and 3) and two-wheelers (category 4)*

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

The traffic flow is represented by a source line. In the modelling of a road with multiple lanes, each lane should be represented by a source line placed in the centre of the lane. Reductions in the number of source lines may be achieved by placing one source line at each outer lane of the road or, in the case of a two-lane road, in the middle of the road itself. Further specifications will be provided in the "Guidance for the competent use of CNOSSOS-EU".

III.2. Sound power emission

III.2.1. General considerations

The sound power of the source is defined in 'semi-free field' according to Section I.2.1, where there are no disturbing objects in its surroundings except for the reflection on the road surface. This description is consistent with the propagation calculation scheme detailed in Chapter VI.

Traffic flow

The noise emission of a traffic flow is represented by a source line characterised by its directional sound power per metre per frequency. 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 road section considered. The implementation of the individual vehicle in the flow requires the application of a traffic flow model ([4], [5]).

If a steady traffic flow of Q_m vehicles of category *m* per hour is assumed, with an average speed v_m (in km/h), the directional sound power per metre per frequency band of the source line $L_{W',eq,line,i,m}$, determined by the vehicle flow, is defined by:

$$L_{W',eq,line,i,m} = L_{W,i,m} + 10 \times \lg\left(\frac{Q_m}{1000 \times v_m}\right) \qquad (III\text{-}1)$$

where $L_{W,i,m}$ is the instantaneous directional sound power in 'semi free-field' of a single vehicle. $L_{W',eq,line}$ is expressed in dB (re. 10^{-12} W/m). These sound power levels are calculated for each octave band i from 125 Hz to 4 kHz.

In Equation (*III-1*), individual road traffic noise sources are modelled as omni-directional sources.[6]

Traffic flow data Q_m should be expressed as a yearly average per time period (day-evening-night), per vehicle class and per source line. For all categories, input traffic flow data derived from traffic counting or from traffic models should be used. However, if input data are missing, default values can be used according to the definitions and specifications to be provided in the "Guidelines for the competent use of CNOSSOS-EU".

Average speed data v_m is a representative speed per vehicle category: in most cases, the maximum legal speed for the vehicle category. Other speed values can be defined according to the specifications to be provided by the "Guidelines for the competent use of CNOSSOS-EU".

Individual vehicle

The instantaneous noise production of a vehicle is defined by two main parameters – category and speed – and corrected for several environmental or specific effects. The calculations are performed with separate speeds for each vehicle category. In the traffic flow, all vehicles of category m are assumed to drive at the same speed, i.e. v_m, the average speed of the flow of vehicles of the 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 for determining the sound power level involves coast-by events, thus making it impossible to distinguish between the two.

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_m (20 km/h ≤ v_m ≤ 130 km/h) is:

$$L_{W,i,m}(v_m) = A_{i,m} + B_{i,m} \cdot f(v_m) \qquad (III\text{-}2)$$

with $f(v_m)$ being a logarithmic function of v_m in the case of rolling and aerodynamic noise, and a linear function of v_m in the case of propulsion noise.

For light, medium and heavy motor vehicles (categories 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 source lines ($L_{W,i,m}$) for m=1, 2 or 3 is defined by:

---

[6] Possible horizontal directivity effects are implicitly taken into account in the procedure to determine $L_{W,i,m}$ by integration of full pass-by events of vehicles. Possible vertical directivity effects are neglected

$$L_{W,i,m}\left(v_m\right)=10\times\lg\left(10^{L_{WR,i,m}\left(v_m\right)/10}+10^{L_{WP,i,m}\left(v_m\right)/10}\right) \qquad \textit{(III-3)}$$

where $L_{WR,i,m}$ is the sound power level for rolling noise and $L_{WP,i,m}$ is the sound power level for propulsion noise. Relevant calculations for these terms are described in Sections III.2.3 and III.2.4 respectively.

For two-wheelers (category 4), only propulsion noise is considered for the source line:

$$L_{W,i,m=4}\left(v_{m=4}\right)=L_{WP,i,m=4}\left(v_{m=4}\right) \qquad \textit{(III-4)}$$

III.2.2. Reference conditions

The source equations and coefficients are derived to be valid under reference conditions in terms of meteorology and traffic. These reference conditions are:

- a constant vehicle speed
- a flat road
- an air temperature τ_{ref} = 20 °C
- a virtual reference road surface, consisting of an average of dense asphalt concrete 0/11 and stone mastic asphalt 0/11, between 2 and 7 years old and in a representative maintenance condition
- a dry road surface
- a vehicle fleet for which the characteristics correspond to the values found for the European average [2]
- no studded tyres.

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_m is used. The sound power level $L_{WR,i,m}$ is expressed by:

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} \times\lg\left(\frac{v_m}{v_{ref}}\right)+\Delta L_{WR,i,m}\left(v_m\right) \qquad \textit{(III-5)}$$

The coefficients $A_{R,i,m}$ and $B_{R,i,m}$ 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.

$\Delta L_{WR,i,m}$ corresponds to the sum of the correction coefficients to be applied to rolling noise emission for specific road or vehicle conditions deviating from the reference conditions:

$$\Delta L_{WR,i,m}(v_m)=\Delta L_{WR,road,i,m}(v_m)+\Delta L_{studded\ tyres,i,m=1}(v_m)+\Delta L_{WR,acc,i,m}+\Delta L_{W,temp}(\tau) \qquad \textit{(III-6)}$$

$\Delta L_{WR,road,i,m}$ accounts for the effect on rolling noise of a road surface with different acoustic properties from the virtual reference surface as defined in Section III.2.2. It includes both the effect on propagation and on generation. The calculation is detailed in Section III.2.6.

$\Delta L_{studded\ tyres,i,m=1}$ is a correction coefficient to be applied to the proportion of light vehicles equipped with studded tyres. This is described in Subsection III.2.3.b.

$\Delta L_{WR,acc,i,m}$ accounts for the effect on rolling noise of a crossing with traffic lights or a roundabout. It essentially integrates the effect on noise of the speed variation. This is described in Section III.2.5.

$\Delta L_{W,temp}(\tau)$ is a correction term for an average temperature τ different from the reference temperature τ_{ref} = 20 °C. This is defined in Subsection III.2.3.c.

For a road surface with acoustic properties similar to the virtual reference surface as defined in Section III.2.2, $\Delta L_{WR,road,i,m}$ = 0 for all categories of vehicles.

For a traffic flow with no light vehicle fitted with studded tyres, $\Delta L_{studded\ tyres,i,m=1}$ = 0

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

The variation with speed of the overall rolling sound power for light, medium and heavy vehicles (categories 1, 2 and 3) in reference conditions is presented in Figure III.2.

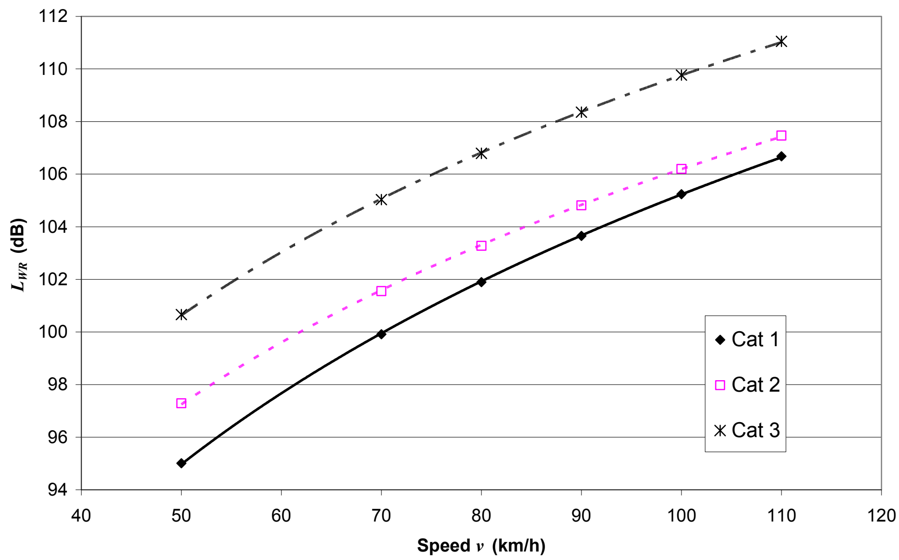

Figure III.2: *Rolling sound power levels in dB for the first three categories of vehicles in reference conditions*

III.2.3.b. Correction for studded tyres

In situations where a significant number of light vehicles in the traffic flow use studded tyres during several months every year, the induced effect on rolling noise must be taken into account. For each individual vehicle of category m=1 equipped with studded tyres, a speed-dependent increase in rolling noise emission ($\Delta_{stud}(v)$) is observed [10] and can be evaluated by:

$$\Delta_{stud,i,m=1}\left(v_{m=1}\right)=\begin{cases} a_i+b_i\times\lg(v_{m=1}/70) & \text{for } 50\le v_{m=1}\le 90 \text{ km/h} \\ a_i+b_i\times\lg(90/70) & \text{for } v_{m=1}>90 \text{ km/h} \\ a_i+b_i\times\lg(50/70) & \text{for } v_{m=1}<50 \text{ km/h} \end{cases} \qquad \textit{(III-7)}$$

where coefficients a_i and b_i are given for each octave band in Table III.A.1.

The increase in rolling noise emission should only be attributed to the proportion of light vehicles with studded tyres and during a limited period T_s (in months) over the year. If Q_{stud} is the average volume of light vehicles per hour equipped with studded tyres during the period T_s (in months), and Q_l the total traffic volume of light vehicles per hour, then the yearly average proportion of vehicles equipped with studded tyres p_s is expressed by:

$$p_s = \frac{Q_{stud}}{Q_1} \times \frac{T_s}{12} \qquad \textit{(III-8)}$$

The resulting correction to be applied to the rolling sound power emission due to the use of studded tyres for vehicles of category m=1 is given by:

$$\Delta L_{studded\,tyres,i,m=1}\left(v_{m=1}\right) = 10 \times \lg\left[\left(1-p_s\right) + p_s 10^{\frac{\Delta_{stud,i,m=1}\left(v_{m=1}\right)}{10}}\right] \qquad \textit{(III-9)}$$

The procedure to establish this correction factor will be explained in the "Guidelines for the competent use of CNOSSOS-EU", together with the default value to be used for p_{s}.

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

III.2.3.c. Effect of air temperature on rolling 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 τ_{ref} = 20 °C. In the case of a different yearly average air temperature τ, the road surface correction should be corrected by:

$$\Delta L_{W,temp}(\tau) = K \times (20 - \tau) \qquad \textit{(III-10)}$$

The correction 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 in general exhibits some frequency dependence. For strategic noise mapping purposes, a simplified noise calculation using a generic coefficient K = 0.08 dB/°C for light vehicles (category 1) and 0.04 dB/°C for heavy vehicles (categories 2 and 3) should be applied for all road surfaces. No correction should be applied for two-wheelers (catergory 4). The correction coefficient should be applied equally on all octave bands from 125 to 4000 Hz.

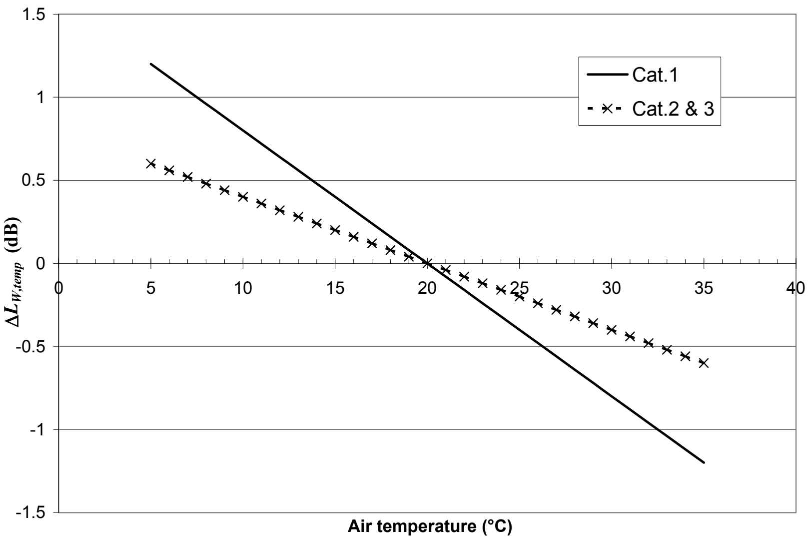

Figure III.3: *Semi-generic temperature correction*

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 $L_{WP,i,m}$ is formulated as follows:

$$L_{WP,i,m} = A_{P,i,m} + B_{P,i,m} \times \frac{\left(v_m - v_{ref}\right)}{v_{ref}} + \Delta L_{WP,i,m}\left(v_m\right) \qquad \textit{(III-11)}$$

The coefficients $A_{P,i,m}$ and $B_{P,i,m}$ 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.

$\Delta L_{WP,i,m}$ corresponds to the sum of the correction coefficients to be applied to propulsion noise emission for specific driving conditions or actual regional conditions deviating from the reference conditions:

$$\Delta L_{WP,i,m}(v_m) = \Delta L_{WP,road,i,m}(v_m) + \Delta L_{WP,acc,i,m} + \Delta L_{WP,grad,i,m}(v_m) \qquad \textit{(III-12)}$$

$\Delta L_{WP,road,i,m}$ accounts for the effect of the type of road surface on propulsion noise. It includes the effect of a porous surface on local propagation of propulsion noise. The calculation is detailed in Section III.2.6.

$\Delta L_{WP,acc,i,m}$ and $\Delta L_{WP,grad,i,m}$ account for deviations related to the driving conditions. They are detailed in Sections III.2.5 and III.2.4.b respectively.

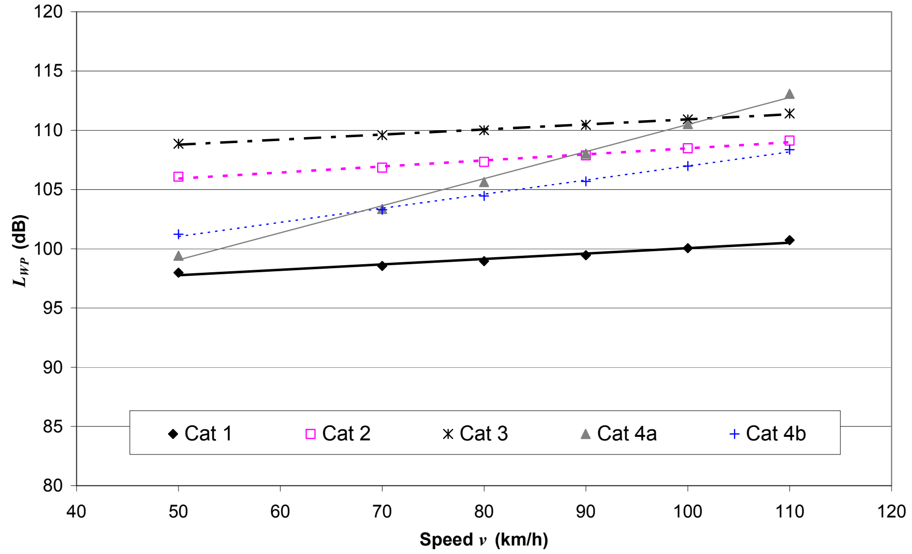

Figure III.4: *Propulsion sound power levels in dB for all categories of vehicles in reference conditions*

NB: Equation *(III-11)* is based on a combination of the relationship between vehicle speed and engine speed and the relationship between engine speed and noise. The first relationship 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 relationship between noise emission and vehicle speed is a reasonable approximation.

For category 4, significant regional variations may occur in emission due to different types of two-wheelers, exhaust systems and driving behaviours. Therefore EU MS, if they wish, may introduce their own emission data provided this is justified and clearly documented within the CNOSSOS-EU database framework. Indications on justification and documentation to be provided will be given in the “Guidelines for the competent use of CNOSSOS-EU”.

III.2.4.b. Effect of road gradients

The road gradient has two effects on the noise emission of the vehicle: first, it affects the vehicle speed and thus the rolling and propulsion noise emission of the vehicle; second, it affects both the engine load and the engine speed via the choice of gear and thus the propulsion noise emission of the vehicle. Only the effect on the propulsion noise is considered in this section, where a steady speed is assumed.

The effect of road gradient on the propulsion noise is taken into account by a correction term $\Delta L_{WP,grad}$, which is a function of the slope s (in %), the vehicle speed v_m (in km/h) and the vehicle class m [15]. The correction term is attributed to all octave bands equally:

For m=1

$$\Delta L_{WP,grad,i,m=1}\left(v_m\right)=\begin{cases}\dfrac{\text{Min}(12\%\,;\,-s)\text{ - }6\%}{1\%} & \text{for } s<\text{-}6\% \\ 0 & \text{for -}6\%\leq s\leq 2\% \\ \dfrac{\text{Min}(12\%\,;\,s)\text{ - }2\%}{1.5\%}\times\dfrac{v_m}{100} & \text{for } s>2\%\end{cases} \qquad (III\text{-}13)$$

For m=2 $$\Delta L_{WP,grad,i,m=2}(v_m) = \begin{cases} \frac{\text{Min}(12\% \,;\, -s) - 4\%}{0.7\%} \times \frac{v_m - 20}{100} & \text{for } s < -4\% \\ 0 & \text{for } -4\% \le s \le 0\% \\ \frac{\text{Min}(12\% \,;\, s)}{1\%} \times \frac{v_m}{100} & \text{for } s > 0\% \end{cases} \qquad (III\text{-}14)$$

For m=3 $$\Delta L_{WP,grad,i,m=3}(v_m) = \begin{cases} \frac{\text{Min}(12\% \,;\, -s) - 4\%}{0.5\%} \times \frac{v_m - 10}{100} & \text{for } s < -4\% \\ 0 & \text{for } -4\% \le s \le 0\% \\ \frac{\text{Min}(12\% \,;\, s)}{0.8\%} \times \frac{v_m}{100} & \text{for } s > 0\% \end{cases} \qquad (III\text{-}15)$$

For m=4 $$\Delta L_{WP,grad,i,m=4} = 0 \qquad (III\text{-}16)$$

The self-contained correction $\Delta L_{WP,grad}$ implicitly includes the effect of slope on speed. Thus, no separate correction is required – in particular on rolling noise – for other effects due to the change in speed when driving uphill or downhill.

For consistency of the road traffic noise emission model, the source line should be divided into line segments with a limited variation in the noise emission (see Subsection VI.2.2.a on source segmentation). Consequently, the slope of the road gradient s should not vary by more than 2% within a segment. The slope input value s to be used in the noise source modelling is the average slope along the line segment.

III.2.5. Effect of the 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: $\Delta L_{WR,acc,i,m} = 0$ and $\Delta L_{WP,acc,i,m} = 0$.

However, EU MS 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 and roundabouts as described below.

For the rolling noise and the propulsion noise of accelerating and decelerating vehicles on a flat road, corrections $\Delta L_{WR,acc,i,m}$ and $\Delta L_{WP,acc,i,m}$ are developed from calculations [15] based on the distance x (in m) from the point source to the nearest intersection of the respective source line with another source line. The correction term is attributed to all octave bands equally:

$$\Delta L_{WR,acc,i,m} = C_{R,m,k} \times \text{Max}\left(1 - \frac{|x|}{100}; 0\right) \qquad (III\text{-}17)$$

$$\Delta L_{WP,acc,i,m} = C_{P,m,k} \times \text{Max}\left(1 - \frac{|x|}{100}; 0\right) \qquad (III\text{-}18)$$

The coefficients $C_{R,m,k}$ and $C_{P,m,k}$ depend on the kind of junction k (k = 1 for a crossing with traffic lights ; k = 2 for a roundabout) and are given in Appendix III-A for each vehicle category. The coefficients are equal for categories 2 and 3. The correction includes the effect of change in speed when approaching or moving away from a crossing or a roundabout.

Note that at a distance $|x| \geq 100$ m, $\Delta L_{WR,acc,i,m} = \Delta L_{WP,acc,i,m} = 0$.

III.2.6. Effect of the type of road surface

III.2.6.a. General principles

The type of road surface significantly influences the noise emission of a vehicle. On a single pass-by event on the roadside, differences of up to 15 dB(A) can be observed for the same vehicle at the same speed in conditions in which 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. In normal practice, the effect of a road surface is evaluated according to international standard procedures by comparing sound pressure levels measured on the roadside that include both source and propagation effects. Therefore, the correction factors should apply to both rolling and propulsion noise and the change in surface impedance should not be included in propagation calculations. However, the effects of dense or semi-dense road surfaces on propulsion noise are small and can reasonably be neglected for all categories of vehicles. Thus, the correction factor on propulsion noise should only be applied in the case of a porous road surface.

The emission coefficients $A_{R,i,m}$, $B_{R,i,m}$, $A_{P,i,m}$, $B_{P,i,m}$ used in Equations (*III-5*) and (*III-11*) and provided in Appendix III-A are valid for the reference road surface defined in Section III.2.2, i.e. a virtual road surface corresponding to an average of dense asphalt concrete 0/11 and stone mastic asphalt 0/11, between 2 and 7 years old and in a representative maintenance condition. For road surfaces with other acoustic properties, the recommendation is to apply a spectral correction factor on rolling noise, and in the case of a porous road surface, to apply spectral correction factors on both rolling and propulsion noise.

The road surface correction factor on rolling noise emission is given by:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_m \times \lg\left(\frac{v_m}{v_{ref}}\right) \qquad \textit{(III-19)}$$

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 125 to 4000 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.

In the case of a porous road surface, the road surface correction factor on propulsion noise is given by:

$$\Delta L_{WP,road,i,m} = \min\left\{\alpha_{i,m};0\right\} \qquad \textit{(III-20)}$$

This correction is identical to that for rolling noise at the reference speed, but with a maximum of zero. Thus, porous surfaces will decrease the propulsion noise, but dense surfaces will not increase it.

EU MS are allowed to use their own national and/or regional road surface provided the data used and basic documentation on the road surfaces (type, basic material description, how the data was obtained, etc) are reported. A procedure on how to establish the road surface coefficients $\alpha_{i,m}$ and β_m and how to translate existing data will be described in the "Guidelines for the competent use of CNOSSOS-EU", together with some examples of road surface corrections.

It should be noted that road surface corrections may vary from place to place 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 and the level of maintenance, with a tendency to become louder over time. In particular, the acoustic lifetime of a low-noise surface is usually shorter than a dense surface, especially for concrete surfaces. Therefore, the road surface correction should be based on the average effect over the representative lifetime. A procedure on how to take this effect into account in the establishment of road surface coefficients will be described in the "Guidelines for the competent use of CNOSSOS-EU".

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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 (*III-5*) (coefficients $A_{R,i,m}$ and $B_{R,i,m}$)

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} \times \lg\left(\frac{v_m}{v_{ref}}\right) + \Delta L_{WR,i,m}\left(v_m\right) \qquad (III\text{-}5)$$

- the correction for studded tyres as defined in Equation (*III-7*) (coefficients a_i and b_i)

$$\Delta_{stud,i,m=1}\left(v_{m=1}\right) = \begin{cases} a_i + b_i \times \lg(v_{m=1}/70) & \text{for } 50 \le v_{m=1} \le 90 \text{ km/h} \\ a_i + b_i \times \lg(90/70) & \text{for } v_{m=1} > 90 \text{ km/h} \\ a_i + b_i \times \lg(50/70) & \text{for } v_{m=1} < 50 \text{ km/h} \end{cases} \qquad (III\text{-}7)$$

- the propulsion noise as defined in Equation *(III-10)* (coefficients $A_{P,i,m}$ and $B_{P,i,m}$)

$$L_{WP,i,m} = A_{P,i,m} + B_{P,i,m} \times \frac{\left(v_m - v_{ref}\right)}{v_{ref}} + \Delta L_{WP,i,m}\left(v_m\right) \qquad (III\text{-}11)$$

- and the correction on rolling and propulsion noise due to acceleration, as defined in Equations (*III-12*) and *(III-13)* (coefficients $C_{R,m,k}$ and $C_{P,m,k}$)

$$\Delta L_{WR,acc,i,m} = C_{R,m,k} \times \text{Max}(1 - \frac{|x|}{100};0) \qquad (III\text{-}17)$$

$$\Delta L_{WP,acc,i,m} = C_{P,m,k} \times \text{Max}(1 - \frac{|x|}{100};0) \qquad (III\text{-}18)$$

Table III.A.1: Coefficients for **category *m*=1** vehicles (passenger cars)

Octave band centre frequency (Hz)	A_R	B_R	A_P	B_P	*a*	*b*
63	79.7	30.0	94.5	-1.3	0	0
125	85.7	41.5	89.2	7.2	0	0
250	84.5	38.9	88.0	7.7	0	0
500	90.2	25.7	85.9	8.0	2.6	-3.1
1000	97.3	32.5	84.2	8.0	2.9	-6.4
2000	93.9	37.2	86.9	8.0	1.5	-14
4000	84.1	39.0	83.3	8.0	2.3	-22.4
8000	74.3	40.0	76.1	8.0	9.2	-11.4

Table III.A.2: Coefficients for **category *m*=2** vehicles (medium heavy vehicles)

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

Table III.A.3: Coefficients for **category *m*=3** vehicles (heavy duty vehicles)

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

Table III.A.4: Coefficients for **category *m*=4a** vehicles (powered two-wheelers ≤ 50 cc)

Octave band centre frequency (Hz)	A_R	B_R	A_P	B_P
63	0.0	0.0	88.0	4.2
125	0.0	0.0	87.5	7.4
250	0.0	0.0	89.5	9.8
500	0.0	0.0	93.7	11.6
1000	0.0	0.0	96.6	15.7
2000	0.0	0.0	98.8	18.9
4000	0.0	0.0	93.9	20.3
8000	0.0	0.0	88.7	20.6

Table III.A.5: Coefficients for **category *m*=4b** vehicles (powered two-wheelers > 50 cc)

Octave band centre frequency (Hz)	A_R	B_R	A_P	B_P
63	0.0	0.0	95.0	3.2
125	0.0	0.0	97.2	5.9
250	0.0	0.0	92.7	11.9
500	0.0	0.0	92.9	11.6
1000	0.0	0.0	94.7	11.5
2000	0.0	0.0	93.2	12.6
4000	0.0	0.0	90.1	11.1
8000	0.0	0.0	86.5	12.0

Table III.A.6: Coefficients for acceleration and deceleration effect *(data to be confirmed during Phase B of CNOSSOS-EU)*

	k = 1: crossing		***k = 2: roundabout***	
Category *m*	C_R	C_P	C_R	C_P
1	-4.5	+5.5	-4.4	+3.1
2	-4.0	+9.0	-2.3	6.7
3	-4.0	+9.0	-2.3	6.7
4a	--		--	
4b	--		--	

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 a 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. See "Remarks on digit 1 and 2" below for further explanation.

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. It presents the relevant descriptors to be used to classify the vehicles in full. These descriptors correspond to properties of the vehicle, which affect the acoustic directional sound power per metre length of the equivalent source line modelled.

The number of vehicles for each type should be determined on each of the track sections for each of the time periods to be used in the noise calculation. It should be expressed as an average number of vehicles per hour, which is obtained by dividing the total number of vehicles travelling in a given time period by the duration in hours of this time period (e.g. 24 vehicles in 4 hours means 6 vehicles per hour). All vehicle types travelling on each track section (defined in Section IV.1.2) will be used.

Remarks on digit 1

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 example of the three-element train in Figure IV.3 below, the outer vehicles are motored and therefore named $m3nn$.

Table IV.1: Classification and descriptors for railway vehicles

Digit	1	2	3	4
Descriptor	**Vehicle type**	**Number of axles per vehicle**	**Brake type**	**Wheel measure**
Explanation of the descriptor	A letter that describes the type	The actual number of axles	A letter that describes the brake type	A letter that describes the noise reduction measure type
Possible descriptors	**h** high speed vehicle (>200 km/h)	**1**	**c** cast-iron block	**n** no measure
	m self-propelled passenger coaches	**2**	**k** composite or sinter metal block	**d** dampers
	p hauled passenger coaches	**3**	**n** non-tread braked, like disc, drum, magnetic	**s** screens
	c city tram or light metro self-propelled and non-self-propelled coach	**4**		**o** other
	d diesel loco	etc.		
	e electric loco			
	a any generic freight vehicle			
	o other (i.e. maintenance vehicles etc.)			

Remarks on digit 2:

There are vehicle types that remain coupled during their lifetime.

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

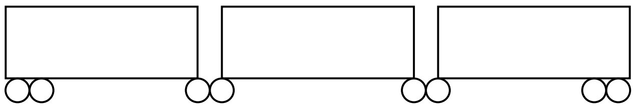

Figure IV.1: *Three elements are coupled without the possibility of uncoupling them in normal conditions*

- In the case of coupled elements, the number of axles can also be odd: e.g. if a common two-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 the one illustrated in Figure IV.1, have a fractional number of axles per vehicle if the train is not 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 ~ 3 axles per unit.
- Also, some freight wagon sets consist of two (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 wayside data collection whether a freight vehicle is part of a set or not, all freight wagon sets have to be considered as separate vehicles.

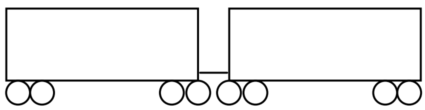

Figure IV.2: *Two elements that are internationally classified as one single vehicle, but in fact behave acoustically as two separate vehicles*

- In the case of calculations, if the number of axles is unknown, four axles per vehicle should 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, etc. 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.

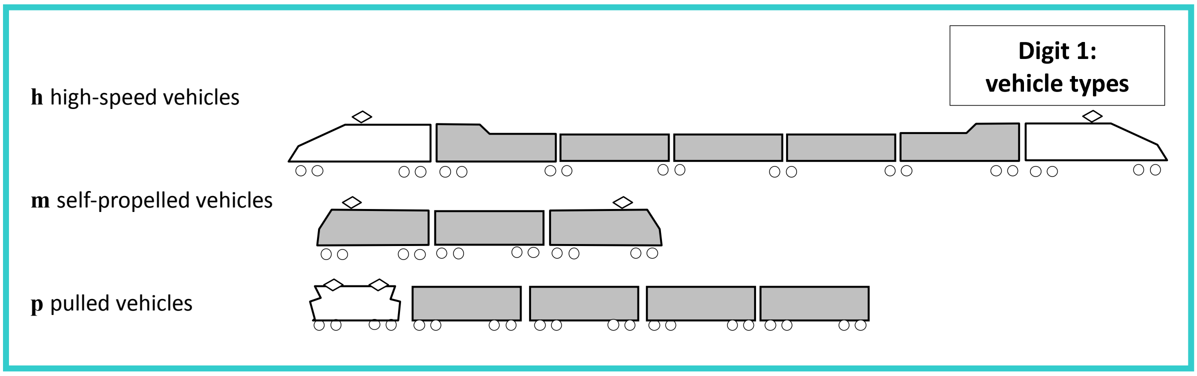

Figure IV.3: *Classification of common vehicle types*

IV.1.2 Classification of tracks and support structure

The existing tracks may differ because there are several elements contributing to and characterising their acoustic properties. The track types used in this method are listed in Table IV.2 below. Some of the elements have a large influence on acoustic properties, while others have only secondary effects. In general, the most relevant elements influencing the railway noise emission are: railhead roughness, rail pad stiffness, track base, rail joints 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's 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.

Table IV.2: Classification of the track types

Digit	1	2	3	4	5	6
Descriptor	**Track base**	**Railhead Roughness**	**Rail pad type**	**Additional measures**	**Rail joints**	**Curvature**
Explanation of the descriptor	Type of track base	Indicator for roughness	Represents an indication of the 'acoustic' stiffness	A letter describing acoustic device	Presence of joints and spacing	Indicate the radius of curvature in m
Codes allowed	**B** Ballast	**E** Well maintained and very smooth	**S** Soft (150-250 MN/m)	**N** None	**N** None	**N** Straight track
	S Slab track	**M** Normally maintained	**M** Medium (250 to 800 MN/m)	**D** Rail damper	**S** Single joint or switch	**L** Low (1000-500 m)

Digit	1	2	3	4	5	6
Descriptor	**Track base**	**Railhead Roughness**	**Rail pad type**	**Additional measures**	**Rail joints**	**Curvature**
	L Ballasted bridge	**N** Not well maintained	**H** Stiff (800-1000 MN/m)	**B** Low barrier	**D** Two joints or switches per 100 m	**M** Medium (Less than 500 m and more than 300 m)
	N Non ballasted bridge	**B** Not maintained and bad condition		**A** Absorber plate on slab track	**M** More than two joints or switches per 100 m	**H** High (Less than 300 m)
	T Embedded track			**E** Embedded rail		
	O Other			**O** Other		

The parameters associated with the different track section types will be found in the CNOSSOS-EU database, which will be developed during phase B of the CNOSSOS-EU process.

Remarks on digit 1

The classification 'C' is considered valid for concrete bridges or steel bridges with a 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, and:

- should be less than the spectrum defined in the 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 1/3 octave bands to be classified as 'E';
- should 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 1/3 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 1/3 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'.

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

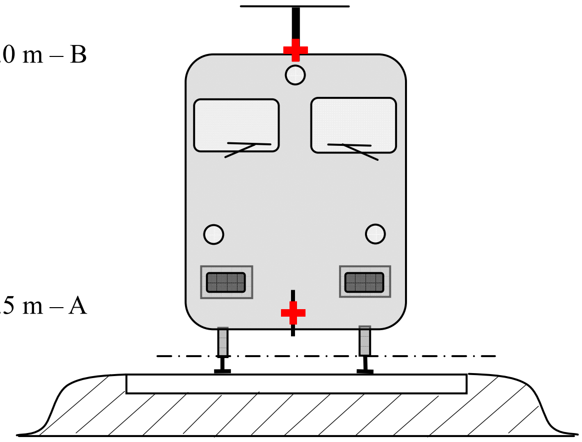

Figure IV.4 : *Equivalent noise sources position*

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 into different categories 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 and 6) noise due to **additional effects** such as bridges and viaducts.

1) The roughness of wheels and railheads, through three transmission paths to the radiating surfaces (rails, wheels and superstructure), constitutes the **rolling noise.** This is allocated to h = 0.5 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 represent the wheel contribution and 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 A) and 4.0 m (source B), 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 A). Louvres and cooling outlets can be at various heights; engine exhausts for diesel-powered vehicles are often at a roof height of 4.0 m (source B). Other traction sources such as fans or diesel engine blocks may be at a height of 0.5 m (source A) or 4.0 m (source B). 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, two source heights are foreseen by the method at 0.5 m (source A), 4.0 m (source B), and the equivalent sound power associated with each is distributed between the two 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 A), and the source at 4.0 m (modelling all over roof apparatus and pantograph, source B). The choice of 4.0 m for pantograph effects is known to be a simple model, and will be considered carefully if the objective is to choose an

appropriate noise barrier height.

4) **Impact noise** is associated with the source at 0.5 m (source A).

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

6) **Bridge noise** is associated with the source at 0.5 m (source A).

__NB__: *In the following sections, source heights are denoted by the index h, and each physical source by the index p, so there can exist various source heights for the same physical source (e.g. aerodynamic noise at 0.5 m and 4.0 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, the directivity coefficient, which is introduced later, depends on the source type and source height, and is therefore linked to both the p and the h coefficients.*

For several situations, detailed information on the sound power contribution of the different sources at different heights is missing.

IV.2. Sound power emission

IV.2.1. General equations

Individual vehicle

The model for railway traffic noise, analogously to 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 a set of sound power per each vehicle ($L_{W,0}$). This description is consistent with the propagation calculation scheme detailed in Chapter V.

Traffic flow

The noise emission of a traffic flow on each track is to be represented, for the purpose of the calculation (Chapter V), by a set of h source lines characterised by its directional sound power per metre per frequency band. This corresponds to the sum of the sound emissions due to the individual vehicles passing by in the traffic flow and, in the specific case of stationary vehicles, taking into account the time spent by the vehicles in the railway section under consideration.

The directional sound power per metre per frequency band, due to all the vehicles passing by, is defined:

- for each frequency band ($\boldsymbol{i}$),
- for each track section ($\boldsymbol{j}$) with the same track type (see Table IV.2),
- for each given source height ($\boldsymbol{h}$) (for sources at 0.5 m h=1, at 4.0 m h=2),

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 ($\boldsymbol{t}$)
- at their different speeds ($\boldsymbol{s}$)
- under the particular running conditions (constant speed) ($\boldsymbol{r}$)

- for each physical source type (rolling, impact, squeal, traction, aerodynamic and additional effects sources such as for example bridge noise) (***p***).

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

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

where

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 (idling)

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

$L_{W',eq,line,x}$ = *x*-th directional sound power per metre for a source line of one combination of *t, s, r, p* on each *j*-th track section

If a steady flow of Q vehicles per hour 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. The noise emission of the vehicle flow in terms of directional sound power per metre $L_{W',eq,line}$ (expressed in dB/m (re. 10^{-12} W)) is integrated by:

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

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's direction of movement (see Figure IV.5).

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

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

In general, directional sound power is obtained from each specific source as:

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

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).

And where $L_{W,0,dir}(\psi,\varphi)$ should, after being derived in 1/3 octave bands, be expressed in octave bands by energetically adding each pertaining 1/3 octave band together into the corresponding octave band.

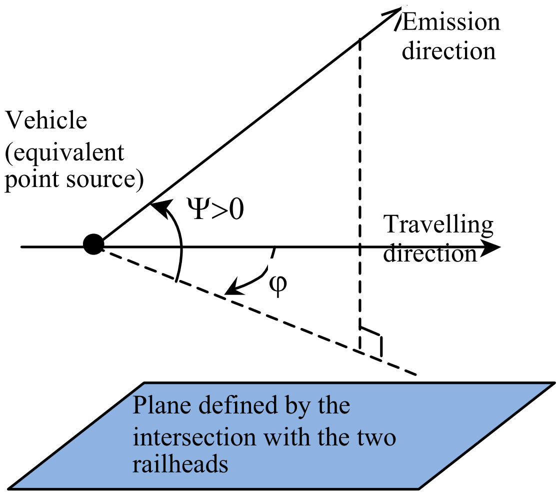

Figure IV.5: *Geometrical definition*

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 $L_{W',tot,dir}$, 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 combination:

- for a 1/3 octave frequency band (***i***)
- for each track section (***j***) (see Table IV.2)
- source height (***h***) (for sources at 0.5 m h=1, at 4.0 m h=2)
- directivity (***d***) of the source

A set of $L_{W,0,dir}(\psi,\varphi)$ are considered for each vehicle-track-speed-running condition combination, each track section, the heights corresponding to h=1 and h=2 and the directivity.

<u>Notes</u>: - *In the rest of this chapter, all the inputs to the calculation expressed in spectral components are in 1/3 octave bands in the range (100 Hz - 5 kHz), although as explained above the overall output of the railway source will be in octave bands.*

- By default, all the subscripts j corresponding to the track section are implicit in all the indicators: they are omitted from the equations in the rest of this chapter to improve their readability.

- *Equation (IV-1) is the general equation: note that several combinations of indexes may not correspond to an existing equivalent sound source, e.g. vehicle type t=1 may only be for constant speed (r=1), therefore the combination of indexes (t,r)=(1,2) does not correspond to an existing equivalent sound source. Also, the directivity may be not the same for all the sources at a given position A, B.*

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 it 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 10 times the logarithm to the base 10 of the square of the mean square value r^2 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:

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

where

r_0 = 1 µm

r = r.m.s. of the vertical displacement difference of the contact surface to the mean level

The roughness level L_r is typically obtained as a spectrum of wave number λ and it must be converted to a frequency spectrum f= v/λ, where f is the centre band frequency of a given 1/3 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 the frequency spectrum by means of the speed, it is necessary to obtain new 1/3 octave band spectra values averaging between two corresponding 1/3 octave bands in the wavelength domain. To estimate the total effective roughness frequency spectrum corresponding to the appropriate train speed, the two corresponding 1/3 octave bands defined in the wavelength domain should be averaged energetically and proportionally.

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

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

The total and effective roughness level for wave-number 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 take into account the filtering effect of the contact patch between the rail and the wheel, and is in dB:

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

where $A_{3,i}$ is the contact filter expressed as a function of the i-th wave-number 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 the 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 measurements 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 wheel sets 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 relate the total effective roughness level with the sound power of the track and the wheels respectively. These functions can be obtained from specific measurements but are also tabulated for some common cases in Appendix IV-B.

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

for h = 1:

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

for h = 2:

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

for h = 3:

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

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

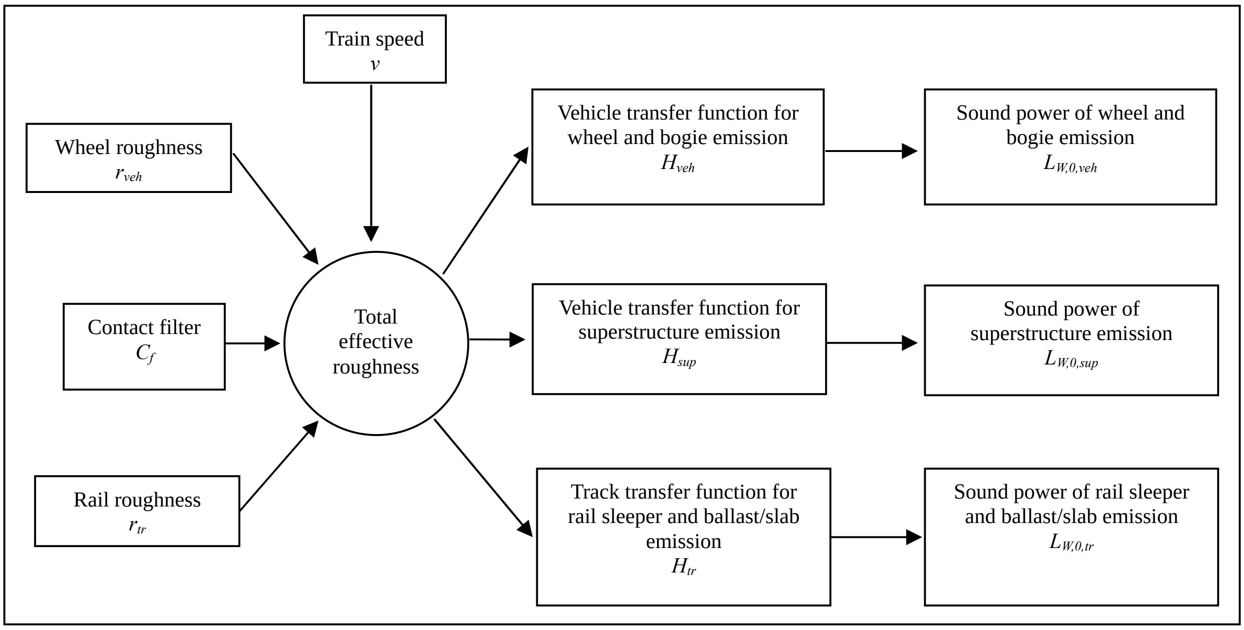

Figure IV.6: *Scheme of the use of the different roughness and transfer function definitions*

Only the running condition at constant speed, the two transfer functions $L_{H,TR,i}$ and $L_{H,VEH,i}$, need to be considered. 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 does not affect the vehicle flow calculation) 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 rolling noise. As it is often localised, it has to be taken into account when choosing track segmentation. If it is to be considered, 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 $L_{R,TOT,i}$ according to Section IV.2.2 and it will be:

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

$L_{R,IMPACT,i}$ is a 1/3 octave band spectrum (as a function of frequency). To obtain this frequency spectrum, a spectrum is given as a function of wavelength λ in Appendix IV-C and should be converted to the required spectrum as a function of frequency using the relation $\lambda = v_{ts}/f$, where f is the 1/3 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, so in the case where multiple impacts are given, the impact roughness level to be used in Equation (*IV-10*) is to be calculated as follows:

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

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

The default impact roughness level is given for a joint density n_l= 0.01 m $^{-1}$, which is one joint per each 100 m of track. Situations with different numbers of joints can be approximated by adjusting the joint density n_l. 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 the case of a series of joints, the increase is extended to between -50 m before the first joint and +50 m after the last joint.

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

Impact noise has to be considered for jointed tracks, and a default n_l of 0.01 is to be used. For impact noise due to switches, crossings and joints in track sections with a speed of less than 50 km/h (30 km/h only for trams and light metro), since the minimum speed of 50 km/h (30 km/h only for trams and light metro) is used to include more effects according to the description of the rolling noise chapter, modelling is to 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 applicability of these sound power spectra should normally be verified on-site, especially for trams.

Taking a simple approach, squeal noise should be considered by adding 8 dB for R<300 m and 5 dB for 300 m<R<500 m to the rolling noise sound power spectra for all frequencies. Squeal contribution should be applied on railway track sections where the radius is within the ranges mentioned above for at least a 50 m length of track.

IV.2.5. Traction noise

Traction noise is generally specific to each characteristic operating condition: constant speed (including deceleration, when it is assumed to be the same noise as for constant speed), acceleration and idling. The source strength modelled here only corresponds to maximum load conditions. This results in the quantities $L_{W,0,const}$ = $L_{W,0,dec}$ = $L_{W,0,acc}$ = $L_{W,0,idling}$ (for constant speed, deceleration, acceleration and idling respectively). 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 Equation (*IV-3)*). It is to be considered only if trains are idling for more than 30 minutes.

These quantities can either be obtained from measurements 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 depend on the train speed:

- Noise from the power train, such as diesel engines (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 measurements 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 better defined load.

There is no a priori attribution of the source sound power to the source heights, and this choice will depend on the specific noise and vehicle assessed. Here it is modelled to be at source A (0.5 m height) and at source B (4.0 m height). In Appendix IV-D, the standard proportion of traction noise to be attributed to the two sources heights is given.

IV.2.6. Aerodynamic noise

Aerodynamic noise is only relevant at high speeds above 200 km/h 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 it may not be necessary to include aerodynamic noise, depending on the vehicle design.

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

$$L_{W,0} = L_{W,0}\left(v_0\right) + \alpha_1 \times \lg\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \qquad (IV\text{-}12)$$

$$L_{W,0} = L_{W,0}\left(v_0\right) + \alpha_2 \times \lg\left(\frac{v_{ts}}{v_0}\right) \text{ dB} \qquad (IV\text{-}13)$$

where

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

α_1 is a coefficient determined from two or more measurement points, for sources at known source heights, for example the first bogie (height = 0.5 m)

α_2 is a coefficient determined from two or more measurement points, for sources at known source heights, for example the pantograph recess heights (height = 4 m).

Example coefficients for α_1, α_2 are given in Appendix IV-E.

IV.2.7. 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 band by:

$$\Delta L_{W,dir,hor,i} = 10 \times \lg\left(0.01 + 0.99 \cdot \sin^2 \varphi\right) \qquad (IV\text{-}14)$$

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

$$\Delta L_{W,dir,ver,i} = \left(\left|\frac{40}{3} \times \left[\frac{2}{3} \times \sin\left(2 \cdot \psi\right) - \sin \psi\right] \times \lg\left[\frac{f_{c,i} + 600}{200}\right]\right|\right) \qquad (IV\text{-}15)$$

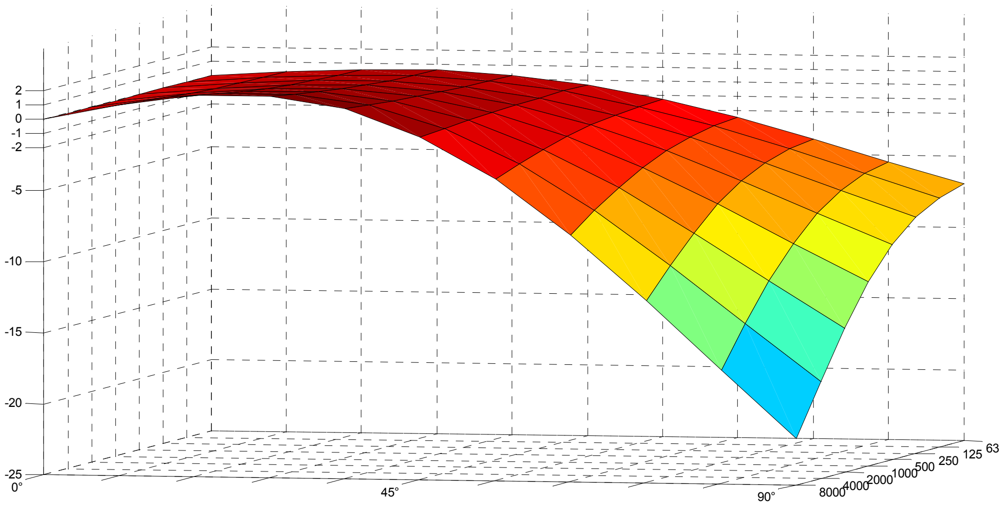

Figure IV.7: *Vertical directivity correction as function of angles and frequencies*

For source B for the aerodynamic effect (4.0 m):

$$\Delta L_{W,dir,ver,i} = 10 \times \lg(\cos^2 \psi) \quad \text{for } \psi<0 \qquad (IV\text{-}16)$$

$$\Delta L_{W,dir,ver,i} = 0 \quad \text{elsewhere} \qquad (IV\text{-}17)$$

Directivity $\Delta L_{dir,ver}$ is not considered for source B (4.0 m) for other effects, as omni-directionality is assumed for these sources in this position.

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 caused by the presence of the train. Because it is not simple to model the bridge emission as an additional source, given the complex shapes of bridges, an increase in the rolling noise is used to account for the bridge noise. The increase is modelled exclusively for the A-weighted overall level and corresponds to a fixed increase in the noise sound power. The sound power of only the rolling noise is modified when considering the correction and the new $L_{W,0,rolling-and-bridge}$ is to be used instead of $L_{W,0,rollingonly}$:

$$L_{W,0,rolling-and-bridge} = L_{W,0,rolling-only} + C_{bridge} \, \mathrm{dB} \qquad (IV\text{-}18)$$

where C_{bridge} is a constant that depends on the bridge type according to the table in Appendix IV-F, and $L_{W,0,rolling-only}$ is the rolling noise sound power on the given bridge that depends only on the vehicle and track properties.

IV.3.2. Correction for other railway-related noise sources

Various sources like depots, loading/unloading areas, stations, bells, station loudspeakers, etc. can be present and are associated with the railway noise. These sources are to be treated as industrial noise sources (fixed noise sources) and should be modelled, if relevant, according to Chapter

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Appendix IV-A

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

Wavelength (cm)	360 mm / 50 kN	680 mm / 50 kN	920 mm / 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

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

Frequency (Hz)	$L_{H,tr,i}$										
	Mono-block on soft rail pad	Mono-block on medium stiffness rail pad	Mono-block on hard rail pad	Bi-block on soft rail pad	Bi-block on medium stiffness rail pad	Bi-block on hard rail pad	Wooden sleepers	Wheel with diameter 920 mm	Wheel with diameter 840 mm	Wheel with diameter 680 mm	Wheel with diameter 1200 mm
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)	$L_{H,veh,i}$									
	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
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 1⁄3 octave band spectrum (as a function of frequency). A default spectrum is given as function of wavelength λ here.

Wavelength (cm)	$L_{R,IMPACT\text{–}SINGLE,i(\lambda)}$
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

The standard proportion of traction noise to be attributed to the two source heights is given here.
$L_{W,0,acc,0.5\mathrm{m}} = L_{W,0,acc,4.0\mathrm{m}} = L_{W,0,acc} - 3$

Frequency	$L_{W,0,acc,i}$ *(traction)*	
	Traction 1: Electric locomotive	Traction 2: 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-E

Parameters for the default calculation of aerodynamic noise are presented here.

The default values suggested are: $\alpha_1 = \alpha_2 = 50$.

Appendix IV-F

C_{bridge} is a constant that depends on the bridge type and can be obtained by comparing the data from measurements taken over the bridge to those not taken over the bridge.

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 factories. Therefore, it is necessary to use an appropriate modelling technique for the specific source under assessment. Depending on the dimensions and the way several single sources extend over an area, with each belonging to the same industrial site, these may be modelled as point sources, source lines or area sources. In practice, the calculations of the noise effect are 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 real sound sources are modelled by means of equivalent sound sources represented by one or more point sources so that the total sound power of the real source corresponds to the sum of the single sound powers attributed to the different point sources.

The general rules to be applied in defining the number of point sources to be used are:

- Line or surface sources where the largest dimension is less than 1/2 of the distance between the source and the receiver can be modelled as single point sources;
- Sources where the largest dimension is more than 1/2 of the distance between the source and the receiver should be modelled as a series of incoherent point sources in a line or as a series of incoherent point sources over an area, such that for each of these sources the condition of 1/2 is fulfilled. The distribution over an area can include vertical distribution of point sources;
- For sources where the largest dimensions in height are over 2 m or 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 significantly better 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 significantly better result.

The position of the equivalent sound sources cannot be fixed, given the large number of configurations that an industrial site can have. Best practices will 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 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)
- Dimensions and orientation
- Operating conditions of the source
- Directivity of the source.

It should be noted that if some of the information listed above is missing and therefore replaced with assumed or somewhat uncertain information, in many cases the resulting industrial noise assessment may not be compromised because the total error is reduced due to many sources contributing to the calculation 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 source lines can be defined:
    - source lines representing conveyor belts, pipe lines, etc., sound power per metre length $L_{W'}$ and directivity as a function of the two orthogonal coordinates to the axis of the source line;
    - source lines representing moving vehicles, each associated with sound power L_W and directivity as a function of the two orthogonal coordinates to the axis of the source line and sound power per metre $L_{W'}$ derived by means of the speed and number of vehicles travelling along this line during day, evening and night;
- For an area source, sound power per square metre $L_{W/m2}$, 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 periods, then a finer distribution of the working hours should be given in sub-periods matching the distribution of meteorological classes. This information should 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 that is to be used for calculations over each time period, C_W in dB is calculated as follows:

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

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 is 12 hours, evening is 4 hours, night is 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, these two cases will always be distinguished:

- a source sound power and directivity is determined and given relative to a certain real source when this is in free field (excluding the terrain effect). This is in agreement with the definition of Section I.2.1 if it is assumed that there is no nearby surface less than 0.01 m from the source and surfaces at 0.01 m or more are included in the calculation of the propagation;
- 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. This is defined in 'semi-free field' according to Section I.2.1. In this case, the nearby surfaces modelled should be excluded from the calculation of propagation.

The directivity will 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 directional 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 also be expressed by means of other coordinate systems such as angular coordinate systems.

V.2.3. Measurements

For 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, where the same sources tend to be present for a very long time and so no averaging takes place. Therefore, each relevant source should be measured to obtain accurate sources and noise maps.

There are 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 such as industrial sites as a whole, to small appliances and machinery.

The following is a classification of such a 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 were originally intended to provide data for the assessment of
    - the source sound power level
    - workplace 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 also rely on these standards for measurements where the objective is to determine the 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 for providing input data for noise mapping purposes, so 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 designed to provide that information.

Accordingly, the end user who is looking for an appropriate measurement method for acquiring input data from his/her particular sound source 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 this is 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 collect appropriate sound power spectra for use in the calculation of industrial noise, it is advisable 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 outdoors (EN 12354-4)**

Appendix V-B

To find default values for industrial noise, a database will be elaborated during Phase B of CNOSSOS-EU and made available by CNOSSOS-EU WG/DT 7.

CHAPTER VI. SOUND PROPAGATION

VI.1. Scope and applicability of the method

This document specifies a method for calculating 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 ground operations and excludes 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 transport infrastructure, the temperature and humidity conditions are defined in a conventional way.

The method provides results per octave band, from 63 Hz to 4 000 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 terms of distance is 800 m for a normal distance to the road. Only receiver points located at least 2 m high 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 direction 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 $M\hat{}N$ 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 by the letter h; equivalent heights measured orthogonally in relation to the mean ground plane are noted by the letter z.

The sound levels, noted by 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 ⊕ in accordance with the following definition:

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

VI.2.2. Geometrical considerations

VI.2.2.a. Source segmentation

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

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.2.1, 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.

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); $k \in$

$\{1,\ldots,n\}$.

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 will 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 increases from the source to the receiver. When the available set of points is not regularly spaced, a new set of points should be determined as follows:

$$\begin{cases} x_j = \dfrac{x_{k+1}-x_k}{\sqrt{\left(x_{k+1}-x_k\right)^2+\left(z_{k+1}-z_k\right)^2}}\left(j-1\right)s+x_k \\ z_j = \dfrac{z_{k+1}-z_k}{\sqrt{\left(x_{k+1}-x_k\right)^2+\left(z_{k+1}-z_k\right)^2}}\left(j-1\right)s+z_k \end{cases} \qquad (VI\text{-}2)$$

where s is the step in metres.

A main characteristic of the set of points produced by Equation *(VI-2)* is that it contains the original scatter points. Since, in general, a perfectly regular set of points cannot be created from a set of points that is not regular, the set of points produced by Equation *(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 $z_k = a_k x+b_k$, $x \in [x_k, x_{k+1}]$; $k \in \{1,\ldots.n\}$, 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:

$$\begin{cases} A = \dfrac{2}{3}\sum_{k=1}^{n-1} a_k\left(x_{k+1}^3-x_k^3\right)+\sum_{k=1}^{n-1} b_k\left(x_{k+1}^2-x_k^2\right) \\ B = \sum_{k=1}^{n-1} a_k\left(x_{k+1}^2-x_k^2\right)+2\sum_{k=1}^{n-1} b_k\left(x_{k+1}-x_k\right) \end{cases} \qquad (VI\text{-}3)$$

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

$$\begin{cases} a = \dfrac{3(2A-B(x_n+x_1))}{\left(x_n-x_1\right)^3} \\ b = \dfrac{2\left(x_n^3-x_1^3\right)}{\left(x_n-x_1\right)^4}B-\dfrac{3\left(x_n+x_1\right)}{\left(x_n-x_1\right)^3}A \end{cases} \qquad (VI\text{-}4)$$

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

Contributions from reflections are taken into account, for example by the introduction of image sources or image receivers.

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 directional sound power per frequency band 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 in 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 meteorological conditions.

VI.2.3.b. Calculation process

For a point source *S* of directional sound power $L_{w,0,dir}$ and for a given frequency band, the equivalent continuous sound pressure level at a receiver point R in given atmospheric conditions is obtained according to the equations following below.

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

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

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

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

where

A_{div}	is the attenuation due to geometrical divergence;
A_{atm}	is the attenuation due to atmospheric absorption;
$A_{boundary,F}$	is the attenuation due to the boundary of the propagation medium in favourable conditions. It may contain the following terms: $A_{ground,F}$ which is the attenuation due to the ground in favourable conditions; $A_{dif,F}$ which is the attenuation due to diffraction in favourable conditions.

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

- either $A_{ground,F}$ ($A_{dif,F}$ = 0 dB) is calculated with no diffraction and $A_{boundary,F} = A_{ground,F}$;

- or $A_{dif,F}$ ($A_{ground,F}$ = 0 dB) is calculated. The ground effect is taken into account in the $A_{dif,F}$ equation itself. This therefore gives $A_{boundary,F} = A_{dif,F}$.

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 section.

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

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

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

where

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

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

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

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

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

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

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

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):

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

<u>NB</u>: The occurrence values for p are expressed in percentages. So for example, if the occurrence value is 82%, Equation *(VI-9)* would have p = 0.82.

VI.2.3.f. Long-term sound level at point 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:

$$L_{tot,LT} = 10 \times \lg\left(\sum_{n} 10^{\frac{L_{n,LT}}{10}}\right) \qquad (VI\text{-}10)$$

where

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

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

$$L_{Aeq,LT} = 10 \times \lg \sum_{i} 10^{\left(L_{tot,LT,i} + AWC_{f,i}\right)/10} \qquad (VI\text{-}11)$$

where i is the index of the frequency band. AWC is the A-weighting correction according to the international standard IEC 61672:2003.

This level $L_{Aeq,LT}$ 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 should not be placed less than 2 m above the ground. This height should be known to the nearest 0.10 m at least to limit any uncertainty on the results, in particular if diffraction is present.

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

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

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

VI.3.2. Elementary propagation paths

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

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.

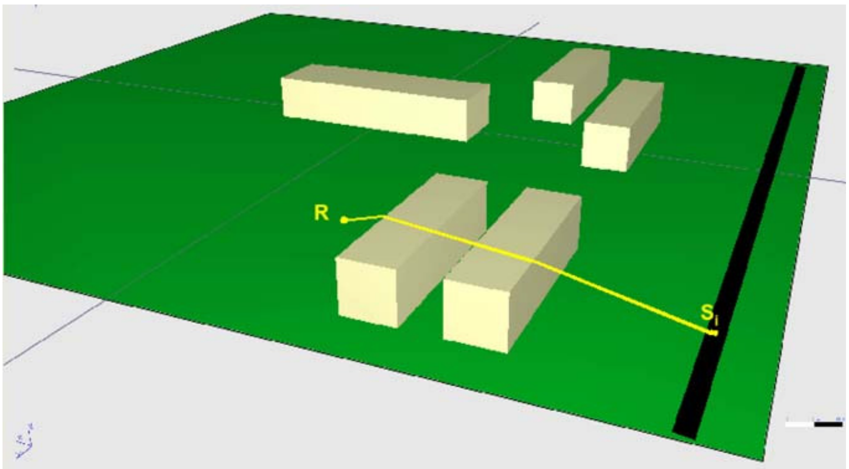


Figure VI.1: *Type 1 path*

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°) obstacles, as shown in Figure VI.2, which may also include diffractions on the horizontal edges of obstacles (see Figure VI.3).

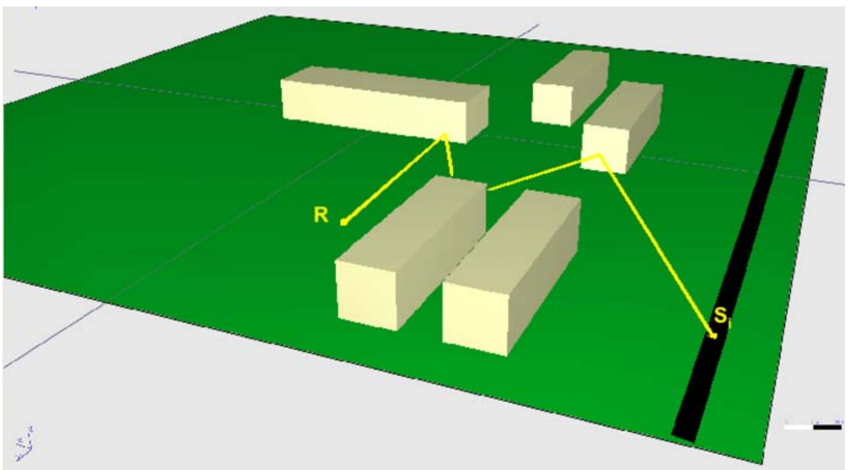


Figure VI.2: *Type 2 path*

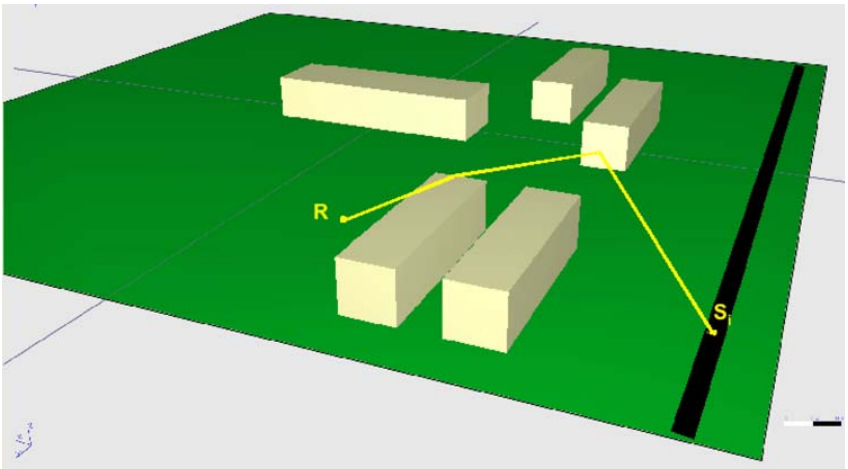


Figure VI.3: *Type 2 path with diffraction on horizontal edge*

The principle is to apply the image method (see Section VI.4.5). 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, which resemble a Japanese screen, and the reflections are taken into account by allocating the sound power of a term which takes into account the reflection coefficient of each vertical surface encountered. If the order equals 1, the power L'_w to be considered is obtained in accordance with Equation *(VI-35)*. If the order equals 2, the power L''_w to be considered is obtained by applying Equation *(VI-35)* 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 Section 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).

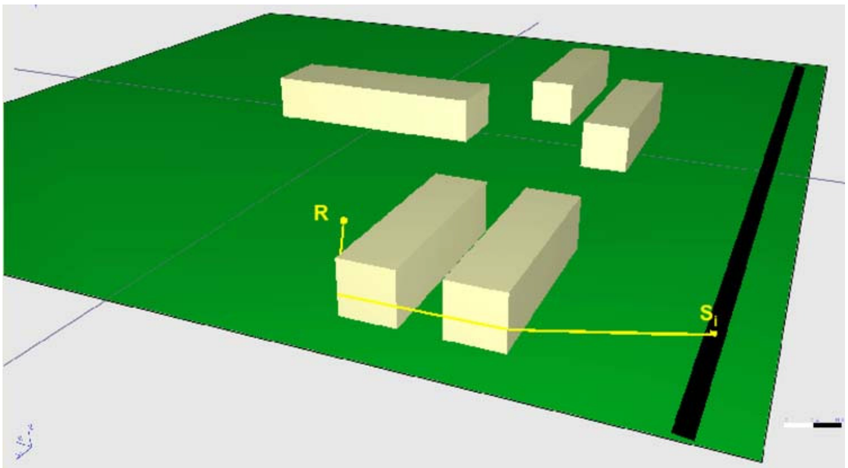


Figure VI.4: *Type 3 path*

The principle is to determine each term of Equation *(VI-33)* in homogeneous conditions and Equation *(VI-34)* in favourable conditions:

- the term $\Delta_{dif(S,R)}$ 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°). The calculation is therefore the same as for type 3 paths with a simple correction of the source power as for type 2 paths.

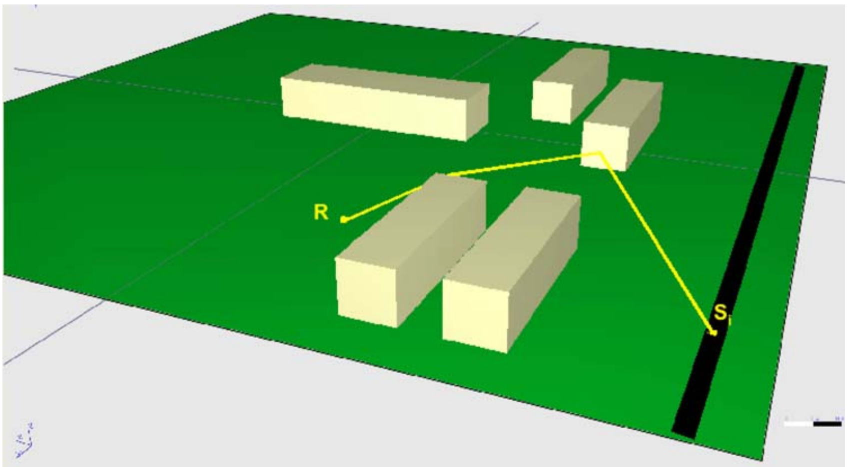


Figure VI.5: *Type 4 paths*

VI.4. Calculations on an elementary path

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

VI.4.1. Geometrical divergence

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

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

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 dB by the equation:

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

where

d is the direct distance between the source and the receiver in m;

α_{atm} is the atmospheric attenuation coefficient in dB/km 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.

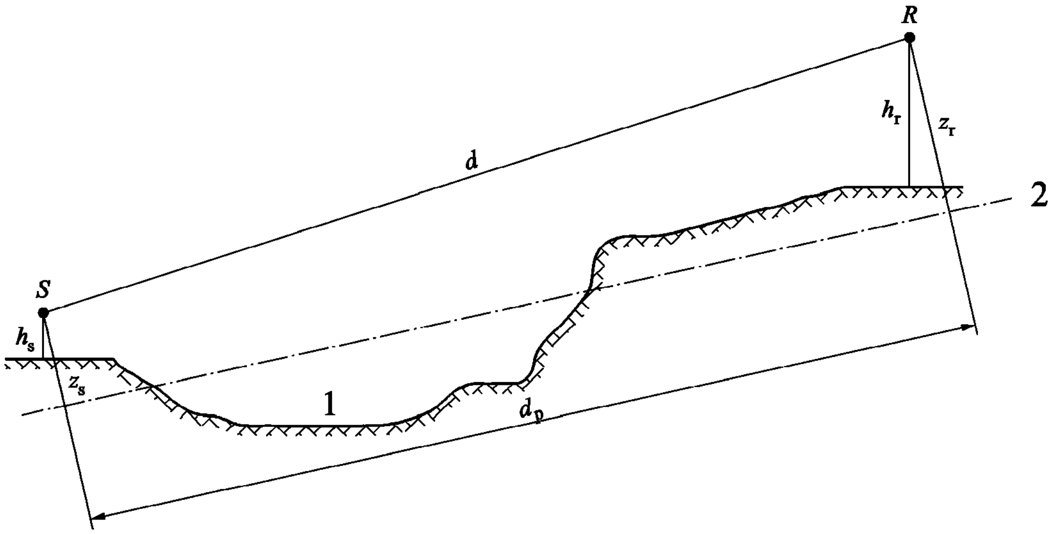
VI.4.3. Ground effect

The attenuation due to the ground effect is mainly the result of the interference between the reflected sound and the sound that 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. However, 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 real heights in the ground effect equations.

In this document, it is customary for real heights above the ground to be noted by h and equivalent heights to be noted by 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 Section VI.2.2.



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 by 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 the 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 coefficient G, between 0 and 1. G is independent of the frequency. Table VI.1 gives the G values for the ground outdoors. In general, the average of the coefficient G over a path takes 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, car park)	F	2000	0.3
Hard surfaces (most normal asphalt, concrete)	G	20 000	0
Very hard and dense surfaces (dense asphalt, concrete, water)	H	200 000	0

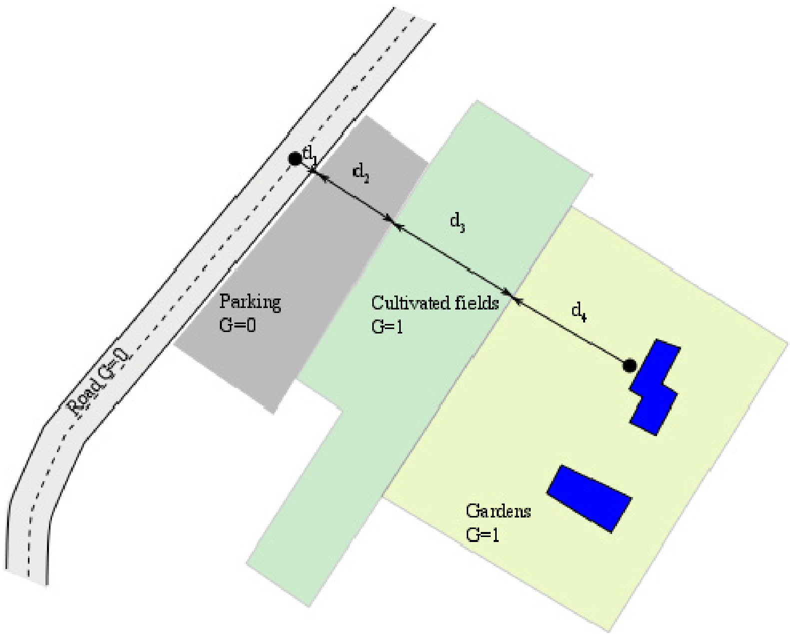
G_{path} is defined as the fraction of absorbent ground present over the entire path covered.

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 is negligible. 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:

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

where G_s is the ground factor of the source area. G_s=0 for road platforms[7]*, 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.



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

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

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

[7] The absorption of porous road pavements is taken into account in the emission model

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}

VI.4.3.c. Calculations in homogeneous conditions

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

if $G_{path} \neq 0$

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

where

$$k = {}^{2\pi f_m}\!/_{c}$$

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

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

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

$$w = 0.0185 \frac{f_m^{2.5}\overline{G_w}^{2.6}}{f_m^{1.5}\overline{G_w}^{2.6} + 1.3 \cdot 10^3 f_m^{0.75}\overline{G_w}^{1.3} + 1.16 \cdot 10^6} \quad \textit{(VI-17)}$$

$\bar{G}_w$ 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 subsections.

$$A_{ground,H,\min} = -3(1 - \overline{G_m}) \quad \textit{(VI-18)}$$

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

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

$\bar{G}_w = G'_{path}$

$\bar{G}_m = G'_{path}$

With diffraction, refer to Section VI.4.4 for the definitions of $\bar{G}_w$ and $\bar{G}_m$.

if $G_{path} = 0$: $A_{ground,H}$ = −3 dB

The term $-3\left(1-\overline{G_m}\right)$ 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 natural land.

VI.4.3.d Calculation in favourable conditions

The ground effect in favourable conditions is calculated with the equation of $A_{ground,H}$, provided that the following modifications are made:

If $G_{path} \neq 0$

a) In the equation of $A_{ground,H}$, 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

$$\begin{cases} \delta z_s = a_0 \left(\dfrac{z_s}{z_s + z_r} \right)^2 \dfrac{d_p^2}{2} \\ \delta z_r = a_0 \left(\dfrac{z_r}{z_s + z_r} \right)^2 \dfrac{d_p^2}{2} \end{cases} \qquad \textit{(VI-19)}$$

a_0 □=2 x 10^{-4} 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 $A_{ground,F}$ depends on the geometry of the path:

$$A_{ground,F,\min} = \begin{cases} -3\left(1-\overline{G_m}\right) & if \quad d_p \le 30\left(z_s + z_r\right) \\ -3\left(1-\overline{G_m}\right) \cdot \left(1 + 2\left(1 - \dfrac{30\left(z_s + z_r\right)}{dp}\right)\right) & otherwise \end{cases} \qquad \textit{(VI-20)}$$

If G_{path} = 0

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

The height corrections δz_s and δz_r convey the effect of the sound ray bending. δz_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 subsections.

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

$\overline{G_w} = G'_{path}$ in Equation *(VI-17)*;

$\overline{G_m} = G'_{path}$.

With diffraction, refer to Section VI.4.4 for the definitions of $\overline{G_w}$ and $\overline{G_m}$.

VI.4.4. Diffraction

As a general rule, the diffraction should be studied at the top of each obstacle located on the propagation path. If the path passes 'high enough' over the diffraction edge, A_{dif} = 0 can be set and a direct view calculated, in particular by evaluating A_{ground} (Section 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_{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 section, 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 equation.

The equations 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 Section VI.4.4.c.

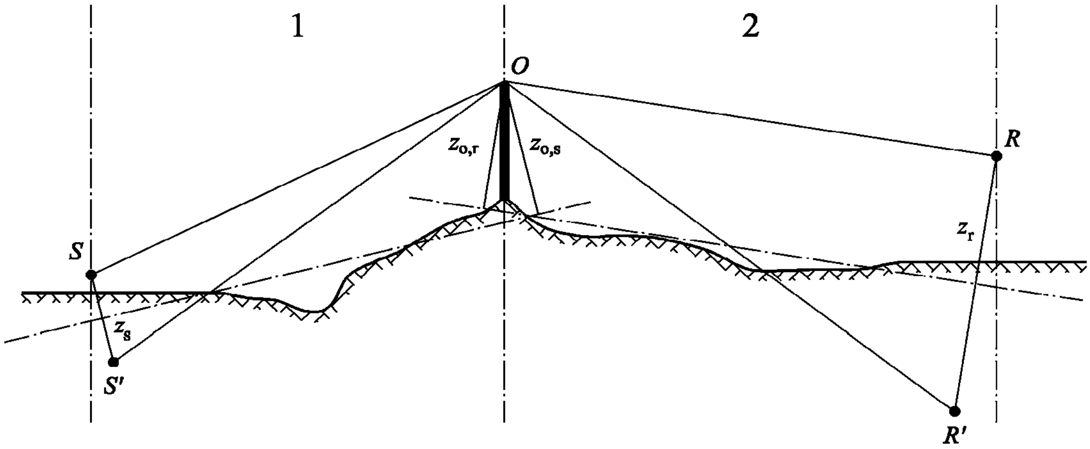
The procedures presented here are used to calculate the attenuations in both homogeneous conditions and favourable conditions. Ray bending is taken into account in the calculation of the path difference and to calculate the ground effects before and after diffraction.

VI.4.4.a. General principles

Figure VI.8 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, $\Delta_{ground(S,O)}$
- a ground effect, receiver side, $\Delta_{ground(O,R)}$
- and three diffractions:
    - between the source S and the receiver R: $\Delta_{dif(S,R)}$
    - between the image source S' and R: $\Delta_{dif(S',R)}$
    - between S and the image receiver R': $\Delta_{dif(S,R')}$.



1: Source side

2: Receiver side

Figure VI.8: *Geometry of a calculation of the attenuation due to diffraction*

where

S is the source;

R is the receiver;

S' is the image source in relation to the mean ground plane source side;

R' is the image receiver in relation to the mean ground plane receiver side;

O is the diffraction point;

z_s is the equivalent height of the source S in relation to the mean plane source side;

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

z_r is the equivalent height of the receiver R in relation to the mean plane receiver side;

$z_{o,r}$ is the 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 first and receiver side second (two mean ground planes), according to the method described in Subsection VI.4.3.a.

VI.4.4.b. Pure diffraction

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

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

where

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

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 Subsection VI.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 VI.9 and VI.11) and if e exceeds 0.3 m (otherwise C'' = 1), this coefficient is defined by:

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

The values of Δ_{dif} shall be bound:

- if $\Delta_{dif} < 0$: $\Delta_{dif} = 0$ dB
- if $\Delta_{dif} > 25$: $\Delta_{dif} = 25$ 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 the following Figures of Subsection VI.4.4.c, based on the situations encountered.

VI.4.4.c.1. Homogeneous conditions

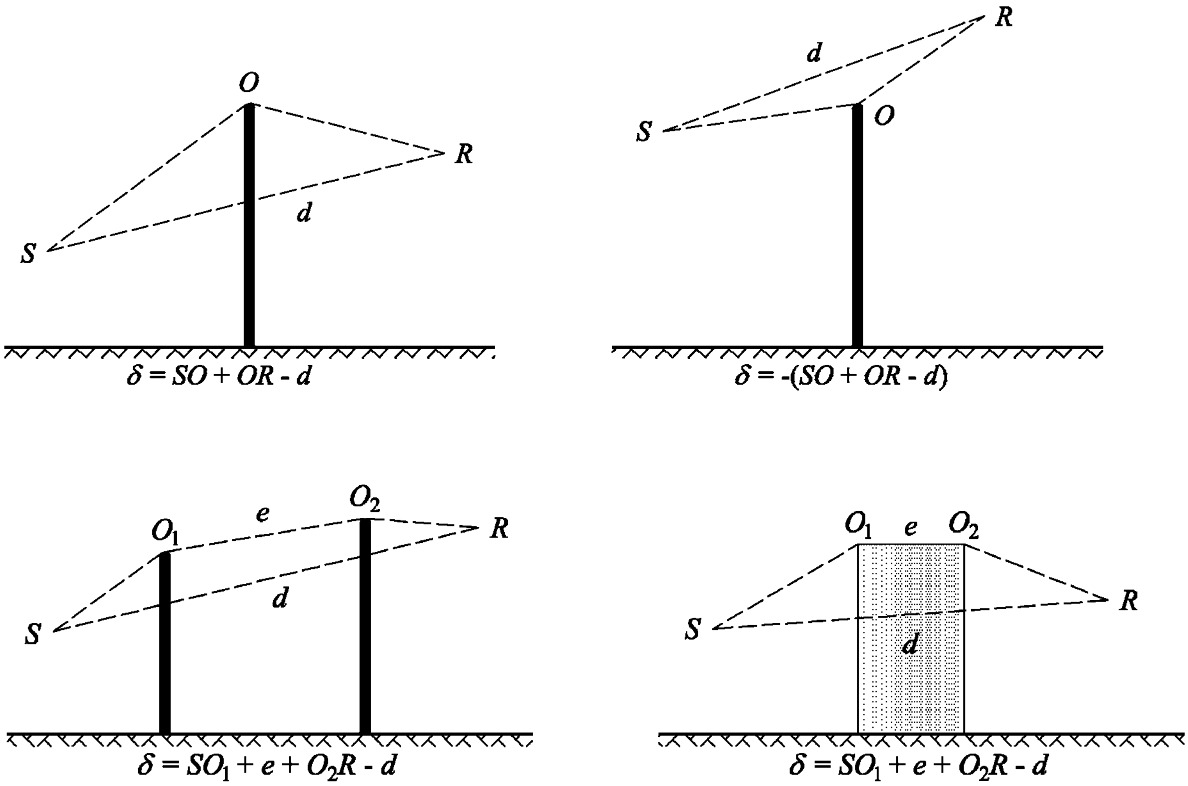


Figure VI.9: *Calculation of the path difference in homogeneous conditions.* O, O_1 *and* O_2 *are the diffraction points*

<u>Note</u>: For each configuration, the expression of δ is given.

VI.4.4.c.2. Favourable conditions

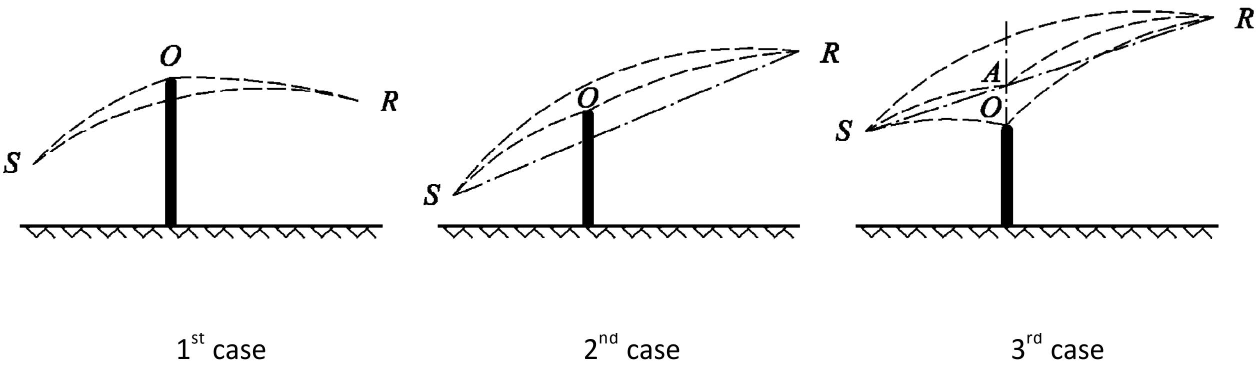


Figure VI.10: *Calculation of the path difference in favourable conditions (single diffraction)*

In favourable conditions, it is considered that the three curved sound rays SO, OR, and SR have an identical radius of curvature Γ defined by:

$$\Gamma = \max\left(1000, 8d\right) \qquad (VI\text{-}24)$$

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

$$\hat{MN} = 2\Gamma \arcsin\left(\frac{MN}{2\Gamma}\right) \qquad \textit{(VI-25)}$$

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 equations are sufficient:

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

$$\delta_F = \hat{SO} + \hat{OR} - \hat{SR} \qquad \textit{(VI-26)}$$

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

$$\delta_F = 2\hat{SA} + 2\hat{AR} - \hat{SO} - \hat{OR} - \hat{SR} \qquad \textit{(VI-27)}$$

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)

$$\delta_F = S\hat{O}_1 + \sum_{i=1}^{i=n-1} O_i\hat{O}_{i+1} + \hat{O}_n R - \hat{SR} \qquad \textit{(VI-28)}$$

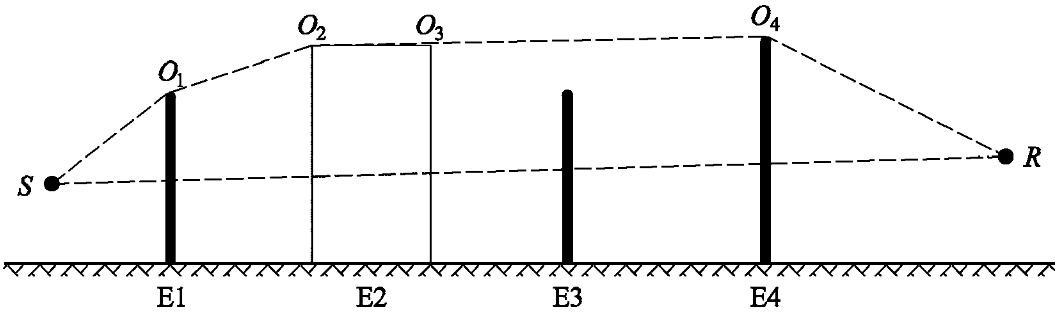


Figure VI.11: *Example of calculation of the path difference in favourable conditions, in the case of multiple diffractions*

In the scenario presented in Figure VI.11, the path difference is:

$$\delta_F = S\hat{O}_1 + O_1\hat{O}_2 + O_2\hat{O}_3 + O_3\hat{O}_4 + \hat{O}_4 R - S\hat{R} \qquad \textit{(VI-29)}$$

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

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

$$A_{dif} = \Delta_{dif(S,R)} + \Delta_{ground(S,O)} + \Delta_{ground(O,R)} \qquad \textit{(VI-30)}$$

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 on the source side, weighted by the diffraction on the source side (see Subsection VI.4.4.d.1);
- $\Delta_{ground(O,R)}$ is the attenuation due to the ground effect on the receiver side, weighted by the diffraction on the receiver side (see Subsection VI.4.4.d.2).

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

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

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 Subsection VI.4.3.c in homogeneous conditions and in Subsection 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: $\bar{G}_m = G_{path}$ in Equation *(VI-17)*, $\bar{G}_m = G'_{path}$ in Equation *(VI-20)*;
- $\Delta_{dif(S',R)}$ is the attenuation due to the diffraction between the image source S' and R, calculated as in Subsection VI.4.4.b;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between S and R, calculated as in Subsection VI.4.4.b.

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

$$\Delta_{ground(O,R)} = -20 \times \lg\left(1 + \left(10^{-A_{ground(O,R)}/20} - 1\right) \cdot 10^{-\left(\Delta_{dif(S,R')} - \Delta_{dif(S,R)}\right)/20}\right) \qquad (VI\text{-}32)$$

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 Subsection VI.4.3.c in homogeneous conditions and in Subsection 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} should indeed be used in the calculation of ground effects,

including for the lower bound term of the equation which becomes -3(1- G_{path}).

- In homogeneous conditions, $\overline{G_w}$ in Equation *(VI-17)* (and $\overline{G_m}$ in Equation (VI-18)) is equal to G_{path};
- In favourable conditions, $\overline{G_w}$ in Equation *(VI-17) (*and $\overline{G_m}$ in Equation *(VI-20)*) is equal to G_{path};
- $\Delta_{dif(S,R')}$ is the attenuation due to the diffraction between S and the image receiver R', calculated as in Section VI.4.4.b;
- $\Delta_{dif(S,R)}$ is the attenuation due to the diffraction between S and R, calculated as in Subsection VI.4.4.b.

VI.4.4.e. Vertical edge scenarios

Equation *(VI.21)* may be used to calculate the diffractions on vertical edges (lateral diffractions). If this is the case, $A_{dif} = \Delta_{dif(S,R)}$ is taken and the term A_{ground} is kept. In addition, A_{atm} and A_{ground} will be calculated from the total length of the propagation path. A_{div} is still calculated from the direct distance d. Equations *(VI-8)* and *(VI-6)* respectively become:

$$A_H = A_{div} + A_{atm}^{path} + A_{ground,H}^{path} + \Delta_{dif,H(S,R)} \qquad \textit{(VI-33)}$$

$$A_F = A_{div} + A_{atm}^{path} + A_{ground,F}^{path} + \Delta_{dif,H(S,R)} \qquad \textit{(VI-34)}$$

Δ_{dif} is indeed used in homogeneous conditions in Equation *(VI-34)*.

VI.4.5. Reflections on vertical obstacles

VI.4.5.a. Attenuation through absorption

The reflections on vertical obstacles are dealt with by means of image sources. Reflections on 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 be applied in 3D.

The obstacles where at least one dimension is less than 0.5 m should be ignored in the reflection calculation, except for special configurations.[8]

Note that 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:

$$L_{W'} = L_W + 10 \times \lg(1 - \alpha_r) \qquad \textit{(VI-35)}$$

where $0 \le \alpha_r < 1$

The propagation attenuations described above (see Sections VI.4.1 to VI.4.4) are then applied to

[8] A network of small obstacles in a plane and at regular intervals constitutes one example of a special configuration

this path (image source, receiver), as for a direct path.

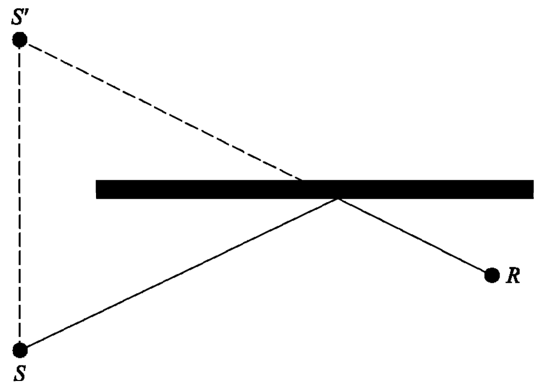


Figure VI.12: *Specular reflection on an obstacle dealt with by the image source method* (S*: source*, S'*: image source*, R*: receiver*)

VI.4.5.b. Attenuation through retrodiffraction

In the geometrical research of sound paths, during 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 with the order of reflection considered.

In the case of a trench (see for example Figure VI.13), the attenuation through retrodiffraction should be applied to each reflection on the retaining walls.

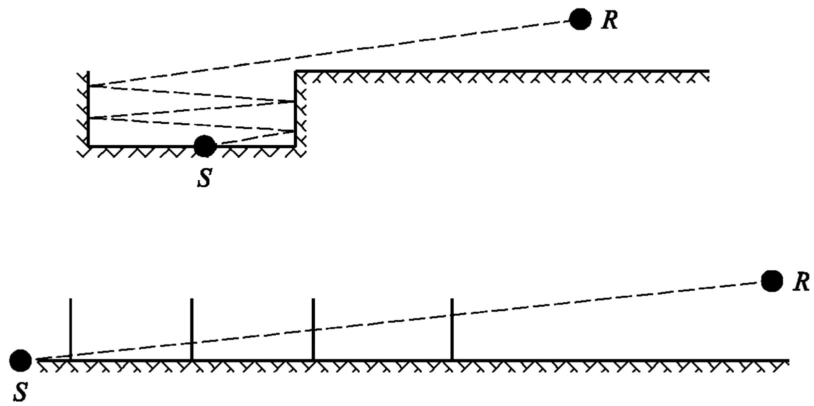


Figure VI.13: *Sound ray reflected to the order of 4 in a track in a trench: actual cross-section (top), unfolded cross-section (bottom)*

In this representation, the sound ray reaches the receiver 'by successively passing through' the retaining walls of the trench, which 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).

$$\delta' = -\left(SO + OR - SR\right) \quad \textit{(VI-36)}$$

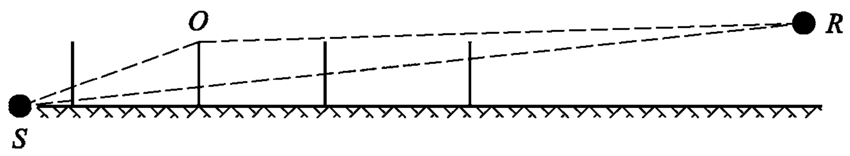


Figure VI.14: *The path difference for the second reflection*

The 'minus' sign of Equation *(VI-36)* means that the receiver is considered here in the clear area.

Attenuation through retrodiffraction $\Delta_{retrodif}$ is obtained by Equation *(VI-37)*, which is similar to Equation *(VI-21)* with reworked notations.

$$\Delta_{retrodif} = \begin{cases} 10C_h \cdot \lg\left(3 + \frac{40}{\lambda}\delta'\right) & \textit{if} \quad \frac{40}{\lambda}\delta' \geq -2 \\ 0 & \textit{otherwise} \end{cases} \quad \textit{(VI-37)}$$

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: :

$$L_{W'} = L_W + 10 \times \lg\left(1 - \alpha_r\right) - \Delta_{retrodif} \quad \textit{(VI-38)}$$

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 the receiver in Equation *(VI-36)*). This principle is illustrated in Figure VI.15.

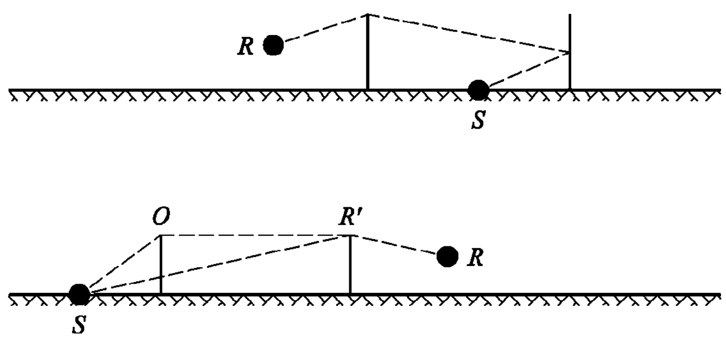


Figure VI.15: *The path difference in the presence of a diffraction: actual cross-section (top), unfolded cross-section (bottom)*

References

1. *French standard, NF S 31-133, Acoustics – Outdoor noise - Calculation of sound levels*, February 2011. ISSN 0335-3931, 71p.

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 the EU (CNOSSOS-EU), the European Commission's JRC in liaison with the DG ENV and the EEA organised, on 19-20 January 2010 in Brussels, an ad hoc workshop on "*Aircraft Noise Prediction*" to bring together EU experts to discuss the aircraft noise module of CNOSSOS-EU.

The workshop on "*Aircraft Noise Prediction*" followed the workshop on the "*Selection of common noise assessment methods in EU*" organised by the JRC, DG ENV and the EEA, which took place on 8-9 September 2009 in Brussels. This latter workshop's recommendations included taking Document 29 3rd Edition of the European Civil Aviation Conference (ECAC) as the basis for the aircraft module of the CNOSSOS-EU method. Some potential improvements were identified and 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 Anleitung zur Berechnung von Lärmschutzbereichen (AzB) method for improving the ECAC Doc. 29 3rd Edition method.

During the 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 scope for improving the existing methods and procedures.

The representatives of the European Commission and the aircraft noise experts participating 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 the commonality of both the methodology and the input data.

Following the formal creation of a CNOSSOS-EU Technical Committee in November 2010, a WG specifically for aircraft noise (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 the CNOSSOS-EU WG 4.

VII.2. Recommended methodology

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

CNOSSOS-EU WG 4 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 International Civil Aviation Organization Aircraft Noise and Performance (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 European Commission, the European Aviation Safety Agency (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 that the CNOSSOS-EU method is aligned with the ICAO method.

ECAC Doc. 29 3rd Edition (December 2005) and the ICAO ANP database version 2 are therefore recommended as the aircraft noise calculation method and database for incorporation into Annex II of the Environmental Noise Directive 2002/49/EC (END).

VII.2.2. ECAC Doc. 29 3rd Edition

The fundamental calculation methodology in Doc. 29 has evolved over several decades. It includes an aircraft performance model where 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 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. The stored NPD data represent noise associated with an infinitely long flight path where flight path parameters remain constant. Various corrections are then 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 2D (power and distance), historically it was 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 a 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 conditions are an air temperature of 15 °C and a headwind of 8 knots (4.1 m/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 reprocessing 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.

> **[NB: At the Noise Regulatory Committee (NRC) meeting which took place on 18 May 2011 in Brussels, the additional resources required to make meteorological adaptations was questioned. Members of CNOSSOS-EU WG 4 are reluctant to commit resources to the development of guidance if the need for adaptation may be dropped and the 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) of the END in terms of aerodromes and airports covered. Although noted as being beyond the terms of reference of WG 4, it was observed that if a major aspect of CNOSSOS-EU is 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 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. Dedicated helicopter aerodromes (heliports) inside agglomerations should also be included.

Although the Directive specifically excludes military aircraft noise, it was noted that 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 a limited number of general aviation aircraft in the ICAO ANP database, coverage is insufficient. It is therefore proposed that general aviation data from the AzB 2008 database are also incorporated, converting them 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 European Commission along with the guidance on applying the recommended method.

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

In contrast to 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 are encouraged with the aim of developing them in the long term into 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. This was considered unacceptable and thus the compromise position recommended, as an 'interim method', applying 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 State's existing national method. The supplementary data would then be published by the Commission along with guidance on its application. Further efforts on helicopter data development are 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, in some cases there is a need for the inclusion of data for military fighter aircraft. It is therefore proposed that the ICAO ANP database version 2 is supplemented with data for military aircraft from both the Integrated Noise Model (INM)/Noisemap and AzB databases.

In terms of calculation methodology, ECAC Doc. 29 3rd Edition will be used, but in the case of 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 exist 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. WG 4 also recommends that the Noise Regulatory Committee (NRC) encourages MS to share data and collaborate to provide common data for the purposes of military aircraft noise calculation where they operate at civil airports. Further efforts on military aircraft data development are 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 discussions 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 of 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, auxiliary power unit (APU) noise and engine run-up (testing) noise. CNOSSOS-EU 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 Brussels, concern was raised about the potential for significant added expenses/resources for little overall contribution, except for very isolated cases. Further efforts on developing this data set 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 a height of 4 m (at the moment ANP data are recorded at a height of 1.2 m)

- 4.0 m is the required position in the 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 currently no clear evaluation of the difference.
- Even if the difference is small, the number of people affected 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 that it is stated 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 it is suggested that the correction be avoided because of: (a) the increase in calculation times, (b) the difficulty in gathering input values on ground type, and (c) the impact that a fragmented noise contour may have when communicated to the public.
- It is recommended that it is stated in CNOSSOS-EU that the ground absorption factor may have an influence. It was suggested that this issue be further investigated, and other alternative approaches also be considered 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 may be positive or negative.
- The inclusion of screening/reflections on obstacles would result in much longer calculation times (and is thus considered impractical) because it would require a much finer resolution grid and more input data on these obstacles, which is not available in some EU MS. Therefore, it is recommended that the screening and reflection effects of these obstacles are not considered in CNOSSOS-EU.

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

Validation of aircraft noise predictions

- The European Commission is interested in assessing noise in residential areas and supports the definition of accurate guidelines that allow 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 the EU (i.e. the aircraft module of CNOSSOS-EU), and a process will be put in place to consider proposed modifications/amendments to ECAC Doc. 29 3rd Edition.
- The fixed-wing calculation method will also apply to General Aviation (GA) aircraft, helicopters and military aircraft. Supplemental data will be provided, along with

guidelines for application to GA, helicopter and military aircraft. For the special case of military fighter aircraft, no engine noise shielding will 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).
- The European Commission will take ownership of and oversee any process for maintaining, developing (including software implementation) and disseminating the CNOSSOS-EU. It is strongly desirable to reach agreement at the international level, which may best be achieved through the ICAO environmental committee, the Committee on Aviation Environmental Protection (CAEP), and involve all relevant European stakeholders (DG ENV, DG MOVE, DG JRC, EU MS, EASA, EEA) associated with 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 these are published in between any reviews of the END (e.g. Adaptation to Technical Progress to be included in the review of the END).

VII.2.12. Generic recommendations regarding the aircraft noise & performance database

- The ICAO 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 MS, notwithstanding differences in aircraft operating procedures across airlines and sometimes airports.
- A robust validation process of ANP data should be formalised 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 Federal Aviation Administration (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 EU airports.
- A database to facilitate the calculation of ground noise from engine run-up (testing) should be included.
- An international agreement may best be achieved through the ICAO environmental committee, CAEP, and would involve all relevant stakeholders including the DG ENV, DG MOVE, DG JRC, EASA and EU MS.

- Transition issues for EU MS 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 following should first be defined:

- the manner in which the information will subsequently be applied
- the key terms and definitions
- the methods and approaches to be applied.

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 summarised 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, and cannot accurately reflect or describe the reporting or legal requirements of the European Commission. The various definitions and methods will need to be revised to reflect the precise requirements of the European Commission, the way the results will be applied, the requirements of other CNOSSOS-EU WGs 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. Therefore, the definitions here do not attempt to reflect the definition of terms such as population, inhabitants or residents.

It should be noted that population exposure assessments that estimate 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 on 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 a permanent structure or a non-permanent structure, such as caravans, mobile homes, converted railway carriages and houseboats, if the non-permanent building being used as permanent residence is stationary and supplied with mains 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, terraced houses, flats, maisonettes, apartments, etc.

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 of the END.

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 of the END defines 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**. This would be consistent with Annex III with respect to dose-response relationships: "dwellings with a quiet façade as defined in Annex VI".

VIII.1.2.6. Most exposed façade

Annex I, 1 of the END 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 on distance may lead to contradictory situations. For this reason a revised 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 of the END 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 purposes of Strategic Noise Mapping, only those individuals who correspond to the people officially registered as residents – as per the latest official statistical database for each registered building or block unit (as per each Member State's relevant regulations) – are to be included (and not 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. These potential errors are considered of minor importance and are therefore 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 sections of Chapter VIII of the present report:

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:

$$Inh_{building} = \sum_{i=1}^{n} Inh_{dwelling_{unit_i}}$$

1B: The number of inhabitants is known only for entities larger than a building, e.g. sides of city blocks, 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 $3\ \mathrm{m}$:

$$H_{building} = NF_{building} \times 3\mathrm{m}$$

If the number of floors is also not known, a default value for the number of floors representative of 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:

$$Inh_{dwelling_{unit_i}} = \frac{DUFS_i}{FSI}$$

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. sides of city blocks, 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 of the area it should be used instead.

If the number of floors of the building is not known, it will be estimated based on the height of the building, $H_{building}$, typically resulting in a non-integer number of floors:

$$NF_{building} = \frac{H_{building}}{3\,\mathrm{m}}$$

If neither the height of the building nor the number of floors is known, a default value for the number of floors representative of the district or the borough will be used.

NOTE: *FSI* estimation

It is known from experience that in Germany the ‘dwelling space per inhabitant’ in most cases is only available from the ‘side of city block’ level upwards. Statistical offices in Germany are recording current information.

For the year 2006, the Federal Statistical Office specified for example the following mean values:

Former federal territory excluding Berlin:
FSI = 44 m² dwelling space per inhabitant

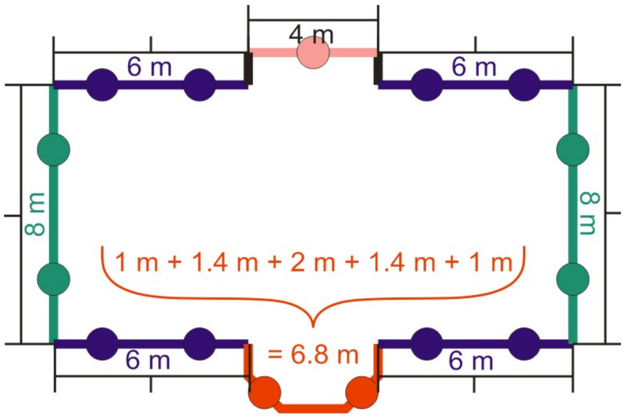
New federal lands including Berlin:

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 the terrain level in front of building façades of residential buildings.

The proposed methodology is based on the German regulation VBEB[9] with some amendments that will better fulfil the list of requirements. The following figure reflects the approach:



a) Segments of a length of more than 5 m are split up into regular intervals of the longest possible length, but less than or equal to 5 m. Receiver points are placed in the middle of each regular interval (**blue**/**green**).

9 Vorläufige Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm (VBEB), Federal Ministry of the Environment (07.02.2007)

b) Remaining segments above a length of 2.5 m are represented by one receiver point in the middle of each segment (**pink**).

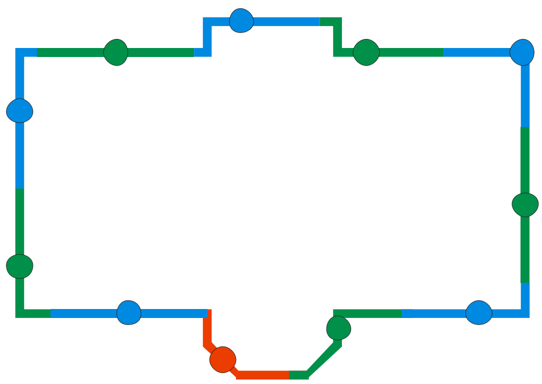
c) Remaining subsequent segments with a total length of more than 5 m are treated as polyline objects in a manner similar to that described in a) and b) (**red**).

d) The influence of any receiver position, for instance the number of inhabitants allocated 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, the 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 the start position onwards, with a receiver position placed at the half-way distance (**blue**/**green**).

b) The remaining section has its receiver point in its mid-point (**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, the 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 façades of buildings. While the former sections of Chapter VIII of the present report focus on this task in the context of strategic noise mapping, Section VIII.3 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 strategic noise mapping, the guiding principle is consistency to guarantee comparability between Member States. However, in the context of 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 there is a noise conflict or the risk of one developing. 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 framework that allows local adaptations that take into account 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 MS, 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-use buildings).

The structure and rhythm of each European city are very important factors for determining the city's dynamics and soundscape, which are part of the city's signature. The behaviour of people living in the city and the climatic conditions require an objective approach to the existing acoustic environment that introduces the noise factor as a psycho-social and design parameter of urban planning. In particular, 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 centres. 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 that take into account local parameters, which 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 sections of Chapter VIII. 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 façades 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 modelled benefit of mitigation measures. The 'standard' height of 4 m above ground used for noise mapping purposes should thus be only taken 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 that the default height of 4 m is adapted if this seems necessary for the specific situation under investigation. Often a set of receiver heights is appropriate for modelling the floor levels having a 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 there may be large numbers of tourists for up to half 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 tourist activities are practically absent, with a correspondingly significant reduction in 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 six months from May to October for the southernmost areas of Europe and the three months from June to August for the northernmost areas. The appropriate population to be assigned should include 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 clearly shows that actions plans require a detailed knowledge of the specific local situation so that they can include an 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 Section 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 it may be possible that even the type of use of individual rooms and the real occupancy is 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 room use.

Diverting from the equal distribution scheme is appropriate in special situations only if detailed information about floor plans has been collected for all the buildings included in the action plan.

VIII.3.2.4. Buildings other than residential buildings

For strategic noise mapping purposes, the assessment focuses on the residential population.. 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 façades of these buildings.

Generally, the method that is part of the equal distribution scheme in Section VIII.2 may be used for this task. The task of assigning population to receiver points in schools or hospitals is more difficult, as there is no residential use.

People either work/study in the building, or generally spend a short period of time there in the case of hospitals. The most appropriate way of assigning people to receiver points depends on the specific goal of the action plan. In some cases, for example when the purpose is to ensure compliance with exposure or noise limits, there may even be no need to assign 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 would be most appropriate.

VIII.3.3. Summary

The consistency of noise maps requires a strictly standardised methodology for the assignment of the population to receiver points at the façades 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"

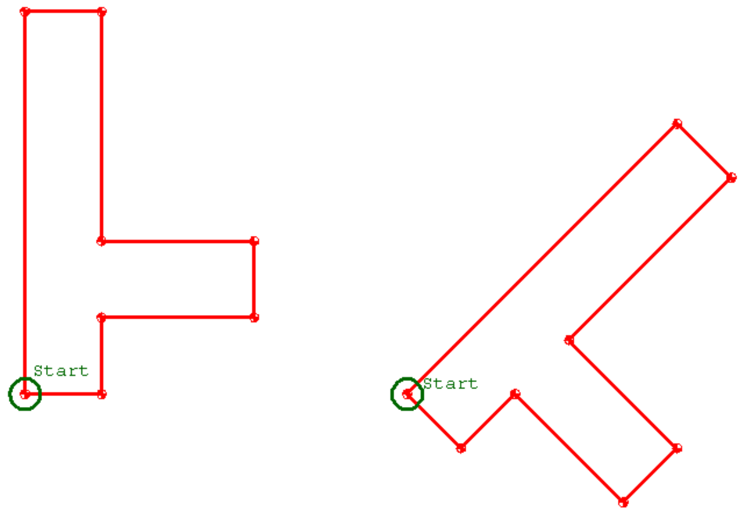
Annex VI, 2.6: "the most exposed façade" and "a quiet façade, as defined in paragraph 1.5"

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:

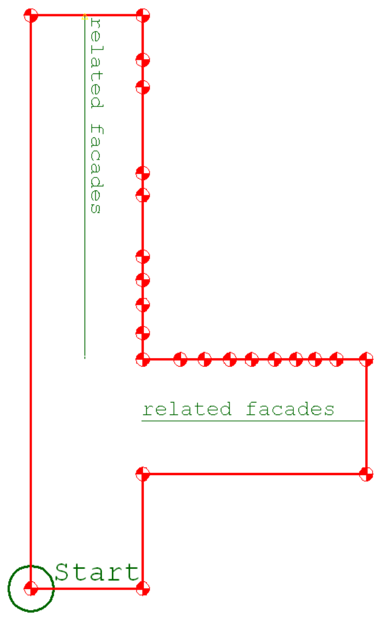
1. Façade receiver point positions right next to the corner of a building should be avoided as they are not representative due to significant changes in acoustical propagation near to the edge of a building. As a kind of 'wage' argument, façade points should represent the 'architectural visual impression' of a building, i.e. should be linked to realistic window positions for typical residential building shapes.
2. The practical distance to the façade for a receiver position 'on the façade' 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 the terrain height at the receiver position.
4. For analysis of the 'quiet façade' the receiver position should be kept 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 the software being used 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, façade noise level statistics will be more in line with what the population experiences if they are not positioned on façades that are at too short a distance to an opposite façade, e.g. of a neighbouring building.
7. Two separate façades of identical length and the same noise exposure will have similar statistical impact, independent of the fact that they are either digitised 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 so have 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 buildings compared.

       Each of the buildings compared 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 buildings compared.

Each of the buildings compared will have its starting vertex in a similar position within its shape.



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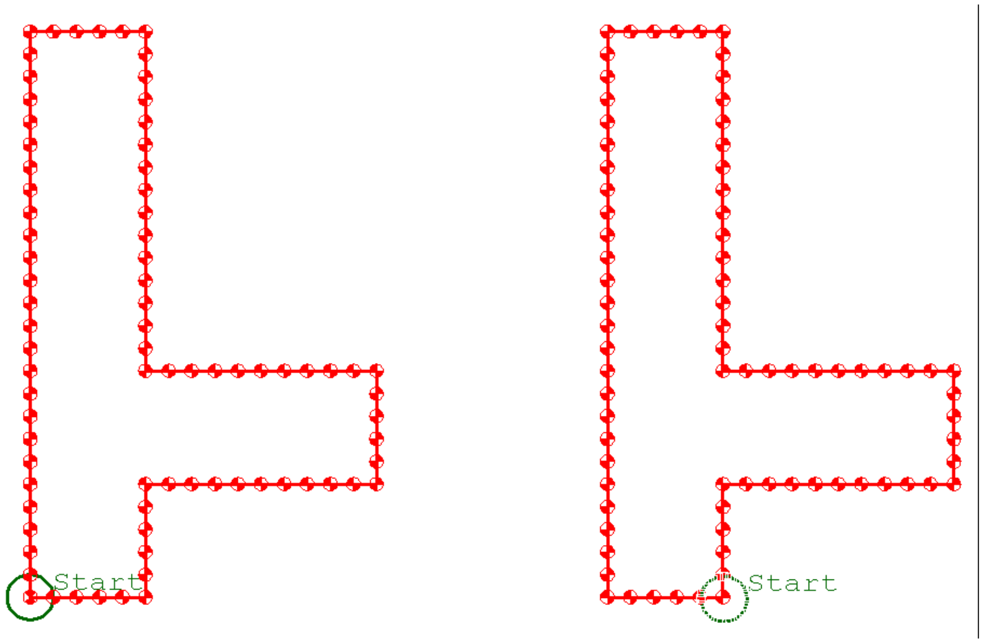
c. Building with identical plan view shape, perhaps in rotated position, but with façade segment length varying for corresponding façade segments of the buildings compared. The starting vertexes of the buildings compared do not have matching positions within the building shape.

This is a useful requirement when similar buildings with an identical number of inhabitants and in identical ambient noise conditions need to result in the same statistical impact. The requirement does 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 the German regulation VBEB. On the right, the starting position is replaced after 5 segments, thus representative façade receiver points will no longer be identical.

CHAPTER IX. GUIDANCE ON THE COMPETENT USE OF CNOSSOS-EU

IX.1. Background

For the first round of the END, which was to be reported to the Commission in December 2007, the competent authorities within the EU MS had an array of differing documents which could be called upon to support their strategic noise mapping activities. These included, but were not limited to, the following key references:

- WG-AEN, *Good Practice Guide for Strategic Noise Mapping and the Production of Associated Data on Noise Exposure*, Version 2;
- WG-AEN, *Presenting Noise Mapping Information to the Public*, March 2008;
- Wölfel et al., *Adaptation and revision of the interim noise computation methods for the purpose of strategic noise mapping*;
- OJEU, Commission Recommendation 2003/613/EC;
- Hepworth Acoustics, NANR 93;
- Hepworth Acoustics, NANR 208;
- EC, ENDRM 2007;
- IMAGINE, WP1 Final report;
- NoMEPorts, Good Practice Guide;
- DIN 45687;
- Various national guidance documents.

It is not known definitively to what extent these guidance documents were utilised during the strategic noise mapping projects of 2007. However, hearsay evidence suggests that, aside from the WG-AEN GPGv2, knowledge of and subsequent use of the other reference documents listed above were inconsistent. Furthermore, as all the knowledge and guidance on best practices was merely informative and non-mandatory, a wide range of 'acceptable' approaches to the strategic noise mapping resulted in 2007. As a result, the information reported to the Commission, and subsequently analysed by the EEA, presents an array of apparent inconsistencies and uncertainties when comparing results between MS.

In the preamble to the END, paragraph 7 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 fractured and disparate nature of the guidance infrastructure around the first round strategic noise mapping naturally produced an array of approaches, and the introduction of uncertainty into the process when considering equivalence and comparability. Evidence from strategic noise mapping projects across Europe suggests that the differences between approaches included at least the following aspects:

- Method of assessment;
- Data quality;
- Differences in:
  - agglomeration definitions
  - small roads in agglomerations
  - population assignment to buildings.

In the light of this experience, it was decided that the development of the CNOSSOS-EU methods would be accompanied by the development of a unified set of guidelines on the practical application of the CNOSSOS-EU methods within the two identified 'fit-for-purpose' applications, namely strategic noise mapping and action planning.

At the kick-off meeting of the CNOSSOS-EU Technical Committee in November 2010, the analysis of the MS feedback on the May 2010 draft JRC Reference Report on CNOSSOS-EU was presented. There were a number of comments raised regarding the guidelines, which may be summarised as:

- Guidance for a competent use of CNOSSOS-EU is required by the EU MS as an integral part of the common methods;
- Nine EU MS also expressed their views on what the guidelines should do:
  - indicate the impact of simplifications of input data;
  - provide instructions on the evaluation of emission data:
    - how to import national databases into CNOSSOS-EU
    - how to introduce new data
  - be flexible enough to accommodate local and regional variations (complex situations such as valley zones).

These comments acknowledge the role of the guidelines as a key element in ensuring that a common method of assessment is implemented and applied consistently across MS, as far as practicable, in order to provide comparability between results as desired within the END.

IX.2. Developing the scope of the CNOSSOS-EU guidelines

The initial scope of the guidelines has developed alongside the CNOSSOS-EU methodological framework. The requirement for unified guidelines was expressed during extensive discussions, and agreed on during the DG JRC workshop on "*Target Quality and Input Values Requirements*", which took place in March 2009 in Ispra. During this workshop it was recommended that the common methods should support development of noise policy on three levels, namely EU, MS and local. It was also recommended that the guidelines would be required to support the application of the methods in two forms of assessment: (1) a simplified approach for strategic noise mapping using default inputs and assumptions, and (2) a more complex approach to support detailed assessments.

In September 2009, DG JRC held a second preparatory workshop in Brussels on "Selection of common noise assessment methods in EU". At this workshop the initial elements of the proposed methods were agreed, and through extensive discussions the initial scope of the proposed guidance began to take shape. At the EURONOISE Conference in October 2009 the "Noise Mapping" workshop presented recommendations from the September 2009 workshop, and discussions were opened to experts from outside the CNOSSOS-EU preparatory WGs. There was a lively debate among the delegates, which predominantly centred on the practical application of the proposed methods, during both the strategic noise mapping and noise action planning phases of the work under the END. These discussions both helped to extend the scope and began to provide some detailed requirements for the guidance.

In March 2010, DG JRC hosted an ad hoc meeting in Ispra with software developers. This was one of a number of ad hoc meetings which have been held since the September 2009 workshop. The first presentation of the initial concept, scope and outline of the guidelines was presented at this meeting, and subsequent discussions produced an outline agreement on the overall form and scope of the guidelines.

The CNOSSOS-EU WG/DT 6 on “Good practice guidelines” was established during the CNOSSOS-EU Technical Committee kick-off meeting which was organised by DG JRC in liaison with DG ENV in November 2011 in Brussels. Subsequently, the first meeting of the CNOSSOS-EU WG/DT 6 was held in Brussels on 15-16 February 2011. During this meeting the work from the CNOSSOS-EU preliminary stage was reviewed in detail by the CNOSSOS-EU WG/DT 6 members, and amended and revised accordingly. The meeting resulted in Terms of Reference for CNOSSOS-EU WG/DT 6 and a report on the outcome of the meeting. These have formed the basis of the Position Paper of the CNOSSOS-EU WG/DT 6, supplemented by the work from the preliminary stage of the process. These are summarised in the remaining sections of Chapter IX of the present report.

IX.3. Concept of the CNOSSOS-EU guidelines

The CNOSSOS-EU guidelines should offer extensive practical guidance to support users in the application of the proposed CNOSSOS-EU methodological framework. The CNOSSOS-EU guidance should be published alongside the technical descriptions of the methods, with the aim of providing a framework for the common implementation of the Environmental Noise Directive (END) 2002/49/EC to support its requirements on comparability and equivalence. Whilst the technical description of the CNOSSOS-EU methodological framework focuses on what the methods entail, the guidance is to focus on how the methods are to be applied in practice.

The proposed approach of establishing a common framework for implementation needs to recognise and accommodate local and regional variations and be flexible in its approach, whilst providing EU, MS, Competent Authorities, guiding experts and stakeholders with a means of understanding the sources and extents of uncertainties within the process. The approach should support and encourage the sharing of data, experience and best practices between stakeholders; support the aims of the INSPIRE Directive; and assist neighbouring MS and competent authorities to meet their obligations. A logical staged approach for undertaking strategic noise mapping under the remit of the END was proposed, with each stage including discussions of specific challenges, solutions, uncertainties, interpretations and guidance as appropriate.

It was proposed that the CNOSSOS-EU Guidance be developed as an interactive web-based tool, which links the guidance with specific aspects of the technical description (see the delivery method section below for details). This was thought to present an opportunity to develop a community of users able to share challenges, solutions and best practices, whilst enabling the guidance to develop in tandem with the experience of applying the CNOSSOS-EU methods within real-world situations.

The primary aim is to bring together the key aspects of best practices currently set out within an array of documents and reports. It was also important to consider that the experience of undertaking the strategic noise mapping under the first round of the Directive in 2007, along with subsequent technical and policy development, has led to a secondary aim that the CNOSSOS-EU guidance be developed and extended beyond the previously available documents. Some of these aspects which were considered, include:

- Data capture methods:
  - How to capture specific noise-related data, such as train emissions, vehicle noise, rail/wheel roughness, road surface data, etc;
- GPGv2 Toolkits:
  - Updated and expanded to deal with CNOSSOS-EU and what should be done when data is or is not available;
- Data schema design:
  - Inputs and outputs for CNOSSOS-EU;
  - Data specification tables and schema diagram;
  - An INSPIRE-compliant, open and extensible standard;
  - Includes rules and guidance on how additional objects and attributes may be added to the schema;
  - Provides a common data format which allows interfacing with data providers, other data owners and cross-border project liaison.
- Use of noise mapping software:
  - User settings and calculation processing;
  - Control of uncertainty as per DIN 45687;
  - Receptor points for population assessment;
  - Grids only for graphics;
  - Guidance on grid resolution for final mapping scale.
- Post-processing:
  - Interpolation of grids for ‘missing’ points or contours, presentation of maps;
  - Population exposure assessment;
  - Reporting to EC (ENDRM);
  - Presentation to the public and stakeholders.

It may be the case that some aspects from existing guidance documents may no longer be considered relevant and other aspects, which are not discussed above, may be added to the CNOSSOS-EU guidance.

IX.4. End-users of the CNOSSOS-EU guidelines

The following end users are identified as potential end users of the CNOSSOS-EU "Good practice guidelines":

WHO	NEEDS
National authority	Understand the financial costs, the complexity and the number of organisations within the MS that need to be involved in the process of implementing the Directive, including transposition.
Competent authority	Coordination, management and production of the resulting 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 (to the EC)	Collect relevant information from the competent authorities.

Note: the 'public' is not a specifically identified end user. As MS and designated bodies have a responsibility to inform the public and undertake public consultations in connection with the activities under the END, the 'public' is not considered to be an end user of the guidelines.

IX.5. CNOSSOS-EU guidance: outline of table of contents

Whilst the overall scope of the WG-AEN GPGv2 has generally been supported since its publication, a number of additional technical issues have been identified during the preparatory phase of CNOSSOS-EU which it may be considered relevant to cover. These are outlined above and include: input data, management of uncertainty, post-processing, and use of noise mapping software.

This led to the proposal, set out below, for an outline of the contents of the CNOSSOS-EU guidance under 12 main sections.

Outline Table of Contents

- 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**
        - To whom is this guidance addressed?

- What can you find in this guidance document?

2. **Implementing the Environmental Noise Directive**
   - Some history
   - Some challenges
   - Aims and objectives following the first round

3. **Application of CNOSSOS-EU**
   - Strategic noise maps under Directive 2002/49/EC
   - Specific detailed assessments
   - Assessment of uncertainty

4. **Overview of strategic noise mapping process**
   - Stages of process under common framework

5. **Areas of assessment**
   - Define agglomerations
   - Define locations of major sources
   - Define areas of noise modelling

6. **Noise calculation methods – practical experience, hints, tips, pitfalls, etc.**
   - Road noise source emission
   - Railway noise source emission
   - Industrial noise source emission
   - Sound propagation
     - Meteorological data
   - Aircraft noise source emission

7. **GIS and data set specifications**
   - Terminology
   - GIS and END requirements
   - Technical specifications of the GIS
   - GIS layers, scale and accuracy
     - Data model
     - Data dictionary
     - Data validation
     - Reference system
     - Metadata
     - GML specification

8. **Noise model data sets**
   - Best practices in noise modelling

- Specification for data capture
- Adaptation of generic GIS data to noise model data
- Data validation
- GPG style Toolkits

9. Noise level calculations

- Overview of calculation process
- Noise assessment systems
    - Software system requirements
    - Test models and protocols
    - Software validation procedure
- Data management strategy
- Model uncertainty
- User-defined calculation settings
- Calculation hardware environment
- Pre-flight checks
- Post-calculation checks

10. Measurements

- Use of measurements in strategic noise mapping
- Road noise source measurement
- Railway noise source measurement
- Industrial noise source measurement
- Meteorological measurements
- Validation and calibration of strategic noise maps
- Medium and long-term noise measurements

11. Post-processing and analysis

- Areas
- Dwellings – from CNOSSOS-EU WG/DT 10
- People – from CNOSSOS-EU WG/DT 10
- Presentation of results
    - Conflict maps, difference maps, consolidated maps

12. Reporting

- ENDRM – from CNOSSOS-EU WG/DT 9 or link through EEA ROD website

IX.6. CNOSSOS-EU guidance: delivery method

Given the extensive nature of the CNOSSOS-EU guidance's outline table of contents, coupled with the wide range of requirements of the five identified sets of end users, it has become clear that a traditional 'flat' document or report structure would not provide an efficient or workable solution for publishing the CNOSSOS-EU guidelines.

With this challenge in mind, a website concept has been developed by DG JRC in order to address a number of the key challenges associated to the requirements for the CNOSSOS-EU guidelines. It is considered that the main benefits of the CNOSSOS-EU guidelines' website concept are as follows:

- *Multi-user authoring*
    - Enables CNOSSOS-EU WG/DT 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 CNOSSOS-EU WG/DT 6 prior to publication.
- *Managed publication*
    - An official version can be published to the user community, whilst the next version is being developed by the CNOSSOS-EU WG/DT 6.
    - 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 tailored to 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 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 to 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.

At present there is a proof-of-concept version of the guidelines website which has been developed within DG JRC to help test out the key ideas and features described above. Below are a number of screenshots for this proof-of-concept website, with specific aspects highlighted using yellow boxes and arrows.

Five embedded levels of use are defined:

- **Level 0: *Overview*:** Framework description of the method, aimed at the 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 people 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 database conversion, tools for introducing new values, use of measurements.

Within each of these levels, pages are group together to match the requirements at that level, as indicated in Figure IX.1.

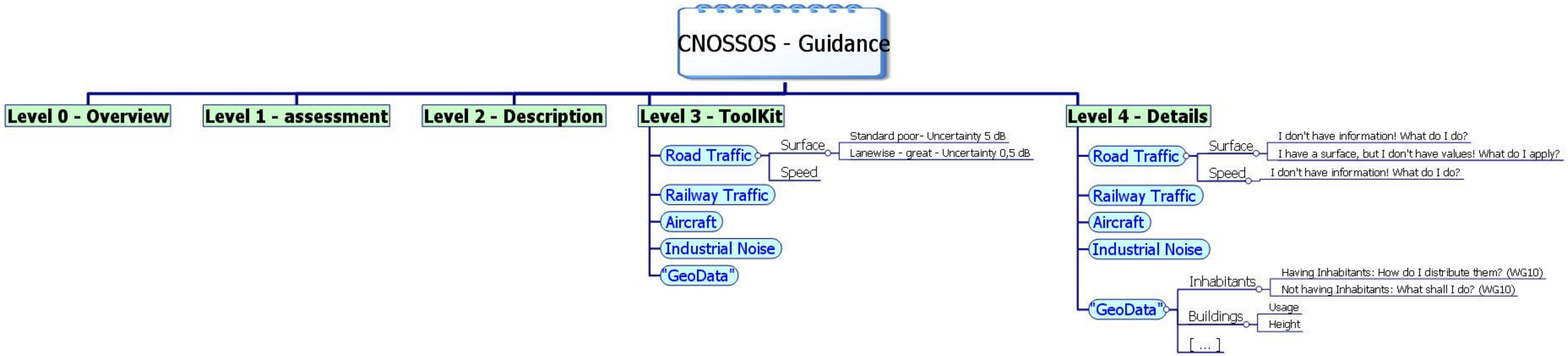
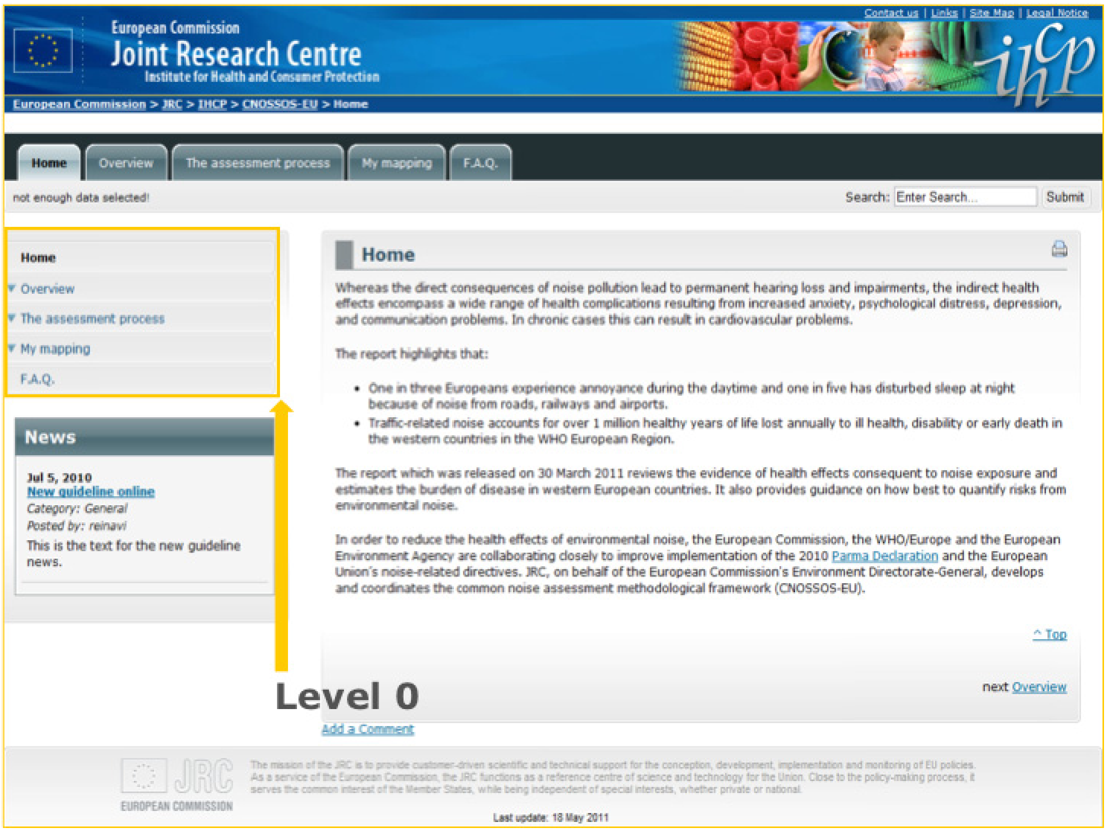


Figure IX.1: *The five embedded levels of use of the CNOSSOS-EU good practice guidelines*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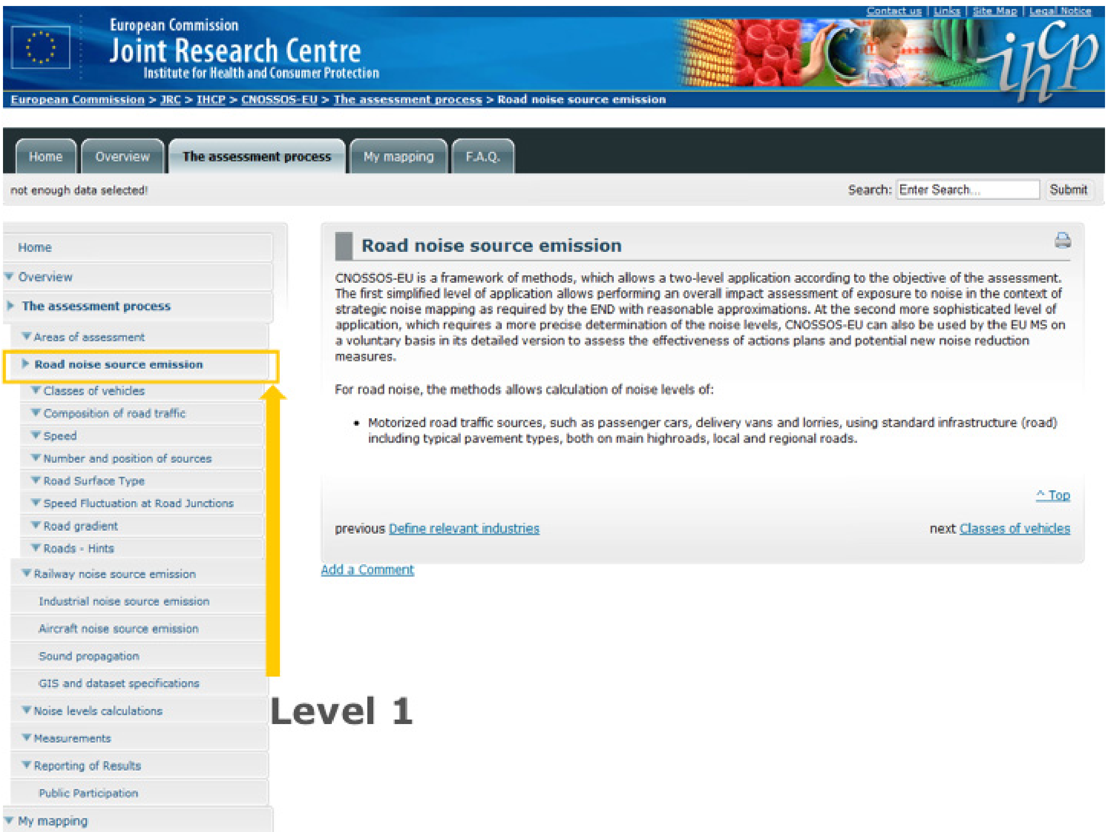
European Commission > JRC > IHCP > CNOSSOS-EU > Home
Home
Overview
The assessment process
My mapping
F.A.Q.
not enough data selected!
Search: Enter Search... Submit
Home
Overview
The assessment process
My mapping
F.A.Q.
News
Jul 5, 2010
New guideline online
Category: General
Posted by: reinavi
This is the text for the new guideline news.
Home
Whereas the direct consequences of noise pollution lead to permanent hearing loss and impairments, the indirect health effects encompass a wide range of health complications resulting from increased anxiety, psychological distress, depression, and communication problems. In chronic cases this can result in cardiovascular problems.
The report highlights that:
• One in three Europeans experience annoyance during the daytime and one in five has disturbed sleep at night because of noise from roads, railways and airports.
• Traffic-related noise accounts for over 1 million healthy years of life lost annually to ill health, disability or early death in the western countries in the WHO European Region.
The report which was released on 30 March 2011 reviews the evidence of health effects consequent to noise exposure and estimates the burden of disease in western European countries. It also provides guidance on how best to quantify risks from environmental noise.
In order to reduce the health effects of environmental noise, the European Commission, the WHO/Europe and the European Environment Agency are collaborating closely to improve implementation of the 2010 Parma Declaration and the European Union's noise-related directives. JRC, on behalf of the European Commission's Environment Directorate-General, develops and coordinates the common noise assessment methodological framework (CNOSSOS-EU).
^ Top
Level 0
next Overview
Add a Comment
JRC
EUROPEAN COMMISSION
Last update: 18 May 2011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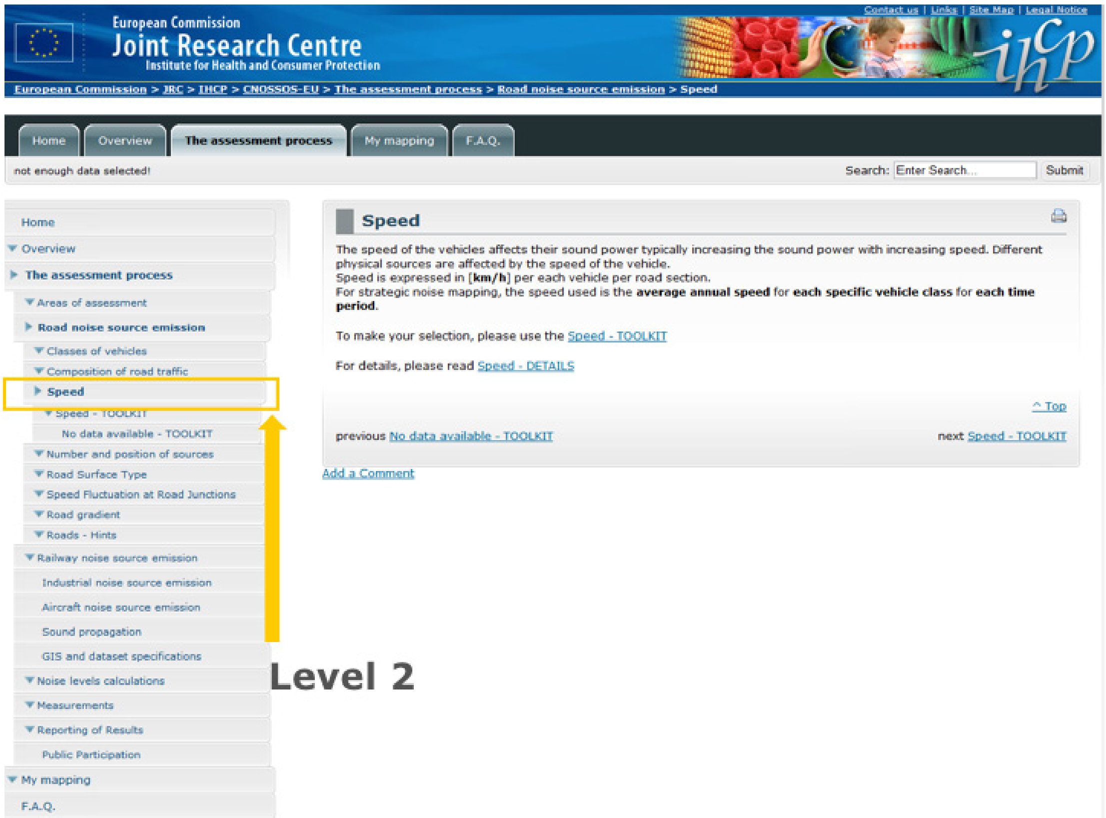
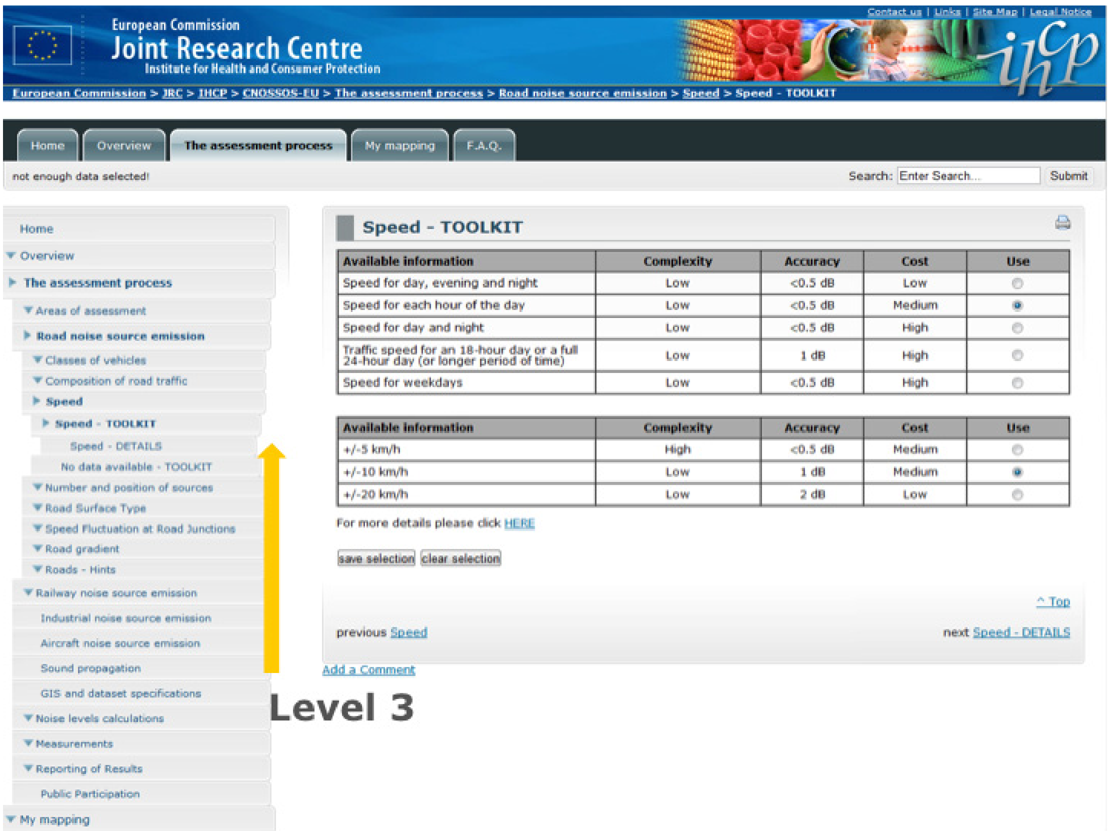
European Commission > JRC > IHCP > CNOSSOS-EU > The assessment process > Road noise source emission
Home
Overview
The assessment process
My mapping
F.A.Q.
not enough data selected!
Search: Enter Search... Submit
Home
Overview
The assessment process
Areas of assessment
Road noise source emission
Classes of vehicles
Composition of road traffic
Speed
Number and position of sources
Road Surface Type
Speed Fluctuation at Road Junctions
Road gradient
Roads - Hints
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
Road noise source emission
CNOSSOS-EU is a framework of methods, which allows a two-level application according to the objective of the assessment. The first simplified level of application allows performing an overall impact assessment of exposure to noise in the context of strategic noise mapping as required by the END with reasonable approximations. At the second more sophisticated level of application, which requires a more precise determination of the noise levels, CNOSSOS-EU can also be used by the EU MS on a voluntary basis in its detailed version to assess the effectiveness of actions plans and potential new noise reduction measures.
For road noise, the methods allows calculation of noise levels of:
• Motorized road traffic sources, such as passenger cars, delivery vans and lorries, using standard infrastructure (road) including typical pavement types, both on main highroads, local and regional roads.
^ Top
previous Define relevant industries
next Classes of vehicles
Add a Comment
Level 1



Level 2



Level 3

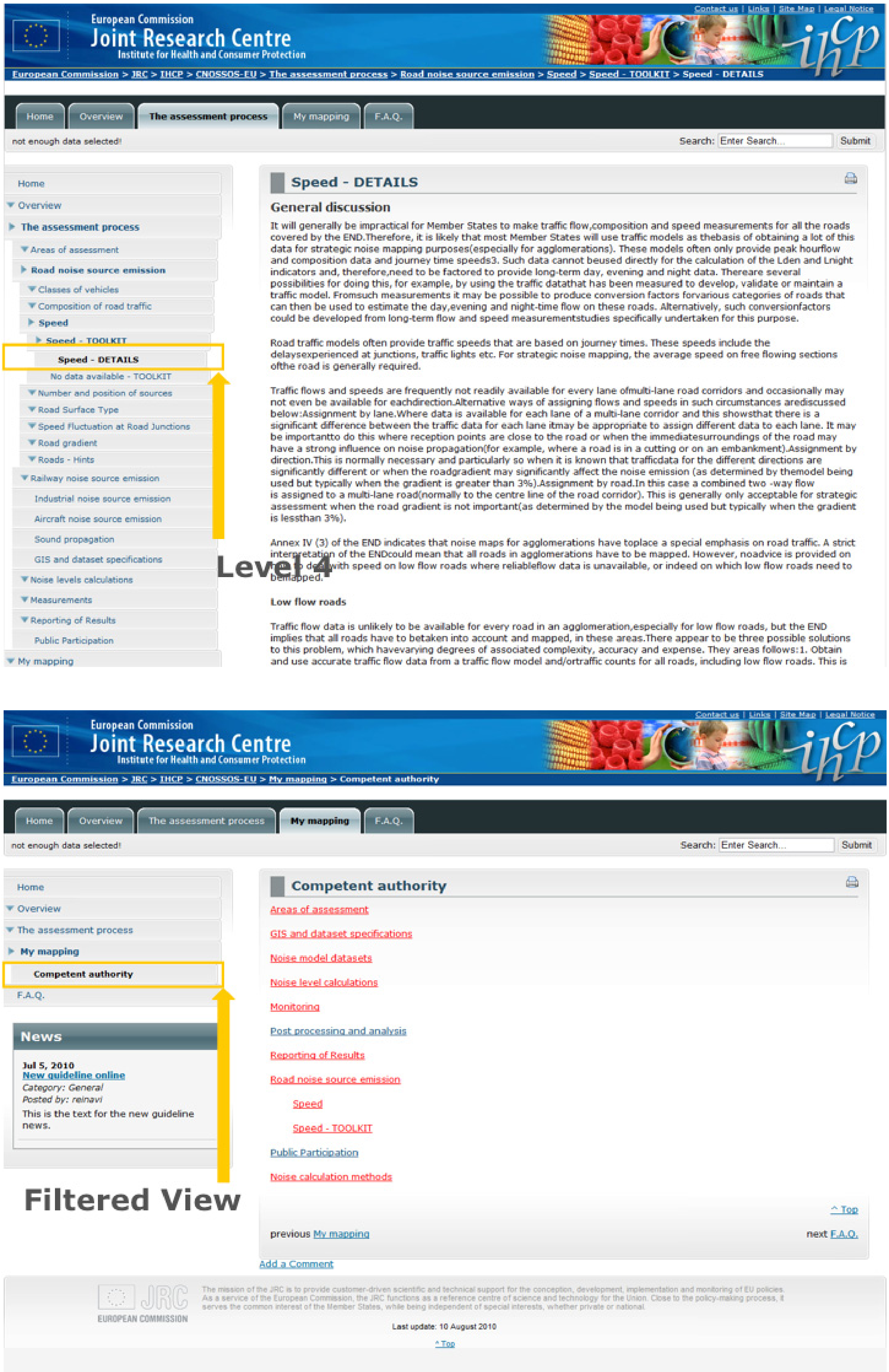


Figure IX.2: *Screenshots of the proof-of-concept CNOSSOS-EU guidelines website*

IX.7. Detailed content of the CNOSSOS-EU guidance

The potential five-level content of the CNOSSOS-EU guidance is shown in detail in the table below. It should be noted that the following table was built by CNOSSOS-EU WG/DT 6 on the basis of the first version of the CNOSSOS-EU methodological framework (May 2010) and should therefore be updated according to the content of the present report and the outcome of phase B of the CNOSSOS-EU process.

ITEM	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	Priority (*)	Method related?
HOME	??					1	no
Overview	??					1	no
1. Introduction		??				1	no
2. Implementing the Environmental Noise Directive		??				1	No
3. Application of CNOSSOS-EU methods		??				2	Yes
4. Overview of strategic noise mapping process		??				1	no
The assessment process							no
5. Areas of assessment		Definition of the main idea behind and explanation of the option to redefine areas, effects of being IN/OUT the area				1	no
Define agglomerations			Discussion on the effect of including/excluding areas	To be defined	To be defined	1	no
Define locations of major sources			Discussion on the effect of including/excluding sources and the definition of major sources within agglomerations	To be defined	To be defined	1	no
Define areas of noise modelling			Area of data to be collected to build the noise model (two different cases for agglomeration and major infrastructure)	To be defined	To be defined	1	no
Define relevant industries			Purpose of the selection. Selection of industrial activities with significant	To be defined	To be defined	1	no

			contribution to noise levels				
6. Noise calculation methods							
Road traffic source							
Road noise source emission		Description in general terms of what parameters are required				1	yes
Classes of vehicles			Lists the classes	Describes the use of 2, 3 or 4 classes	Rolling and propulsion noise coefficients A_R, B_R, A_P, B_P and C_P, and other parameters such as traffic flow, directivity, road surface effect are also class-dependent. Link with national database	1	yes
Number and position of sources			Describes the source position for each class of vehicle (1 sentence)	Reduction in the number of sources	To be defined	1	yes
Traffic flow			Describes the generic model (1 sentence)	What parameter to use, effect of vehicle class distribution	To be defined	1	yes
Speed			Describes speed effect	What speed parameter to consider	To be defined	1	yes
Rolling noise emission			Describes rolling noise calculation. Requires speed as input parameter	Link with speed item Definition of A_R and B_R coefficients	Update rolling noise coefficients A_R and B_R, link with national database	1	yes
Propulsion noise			Requires speed and acceleration as input parameters	Link with speed and acceleration parameters	Propulsion noise coefficients A_P, B_P and C_P, link with national database	1	yes
Effect of type of road surface			Description of reference road surface, potential effect of road surfaces	Lists the existing types of road surfaces and the expected noise reductions (look-up table according to MS)	Link with measurement standards and national databases	1	yes
Source directivity			Description of directivity and expected effect	Advice on when to use it (specific tests)		3	yes
Acceleration			Description of the effect of acceleration	Advice on when and how to use it, situations where it can be considered and where it should be avoided		2	yes

Effect of road gradient			Describes the effect of road gradient and combination with acceleration	Advice on when and how to use it, addresses the discontinuities with flat parts, what to do with slopes >6%		2	yes
Effect of temperature			Temperature (description of the effect)	What parameter to select (yearly average, etc?)		2	yes
Regional and fleet-specific effects			Wetness of road surface	Advice on when to use it and what parameter to use		3	yes
			Truck with multi-axle	Advice on when to use it and what parameter to use		3	yes
			Truck with specific tyre mounting	Advice on when to use it and what parameter to use		3	yes
			Vehicle weight/tyre width	Advice on when to use it and what parameter to use		3	yes
			Studded tyres	Advice on when to use it and what parameter to use		3	yes
			Proportion of vans	Advice on when to use it and what parameter to use		3	yes
			Engine fuel/energy	Advice on when to use it and what parameter to use		2	yes
			Truck with high exhaust system	Advice on when to use it and what parameter to use		3	yes
			Structural vibration of bridges	Advice on when to use it and what parameter to use		3	yes
			Tunnel openings	Advice on when to use it and what parameter to use		3	yes
Railway source emission							
Railway noise source emission		Description in general terms of what parameters are required				1	
Classes of vehicles			Lists the six basic classes	Describes the simplified subdivision (BEWARE! THIS IS AN ALTERNATIVE TO THE USE OF THE FOLLOWING PARAMETERS!)	Mentions that these are simplified versions, and what they mean given their simplifications	1	yes
Number of axles per vehicle			Synthetic definition of the number of axles	Describes the use and sub-classification according to six specific descriptors	Detailed description of the axles per vehicle parameter	2	yes

Brake type			Synthetic definition of the brake type relevance	Describes the use and sub-classification according to six specific descriptors	Detailed description of the brake type parameter	1	yes
Vehicle type			Synthetic definition of the vehicle type classification	Describes the use and sub-classification according to six specific descriptors	Detailed description of the vehicle type	2	yes
Load			Synthetic definition of the load parameter and its effectiveness	Describes the use and sub-classification according to six specific descriptors	Detailed description of the load effect	3	yes
Wheel diameter			Synthetic definition of the wheel diameter and its effect on noise	Describes the use and sub-classification according to six specific descriptors	Detailed description of the wheel diameter effect	3	yes
Wheel measure			Presentation of possible wheel reduction measures and their effects	Describes the use and sub-classification according to six specific descriptors	Detailed description of the noise reduction measure attached to the wheel	2	yes
Classes of tracks and support structures			Lists the six basic classes	Describes the simplified subdivision		1	yes
Track base			Defines the track base and how it affects noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the track base parameter	3	yes
Roughness			Defines the roughness and how it affects noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the roughness parameter (e.g. how to measure it)	1	yes
Rail pad type			Defines the rail pad and how it affects rail noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the rail pad type parameter	2	yes
Rail fastener			Defines the rail fastener and how it affects railway noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the rail fastener parameter	3	yes
Sleeper type			Defines the sleeper type and how it affects railway noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the sleeper type parameter	3	yes
Rail type			Defines the rail type and how it affects railway noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the rail type parameter	3	yes
Sleeper spacing			Defines the sleeper spacing and how it affects railway noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the sleeper spacing parameter	3	yes

Additional measures			Describes what kind of additional measures can be taken and for what reasons	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the additional measures parameter	2	yes
Rail joints			Describes rail joints, where they are found and how this affects noise	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the rail joints parameter	2	yes
Curvature			Describes why curvature is important and what its effects are	Describes the use and sub-classification following 11 specific descriptors	Detailed description of the curvature parameter	2	yes
Dynamic characteristics			Expresses the overall dynamic characteristics of the track	Describes the use and sub-classification following 11 specific descriptors (BEWARE! THIS PARAMETER IS USED TO EVALUATE THE EFFECT OF RAIL PAD+SLEEPER+RAIL TYPE!)	Detailed description of the dynamic characteristics parameter There is a need to clarify the use of this parameter in place of other parameters	3	yes
Number and position of sources			Describes the possible position of sources (1 sentence)	Uses five source heights or reduces the number of sources to two (BEWARE! THIS PARAMETER BLOCKS THE CHOICE OF IMPACT SQUEAL BRAKING AND ADDITIONAL EFFECTS)	Explains the reasons for and effects of simplification, and what should and should not be included in the simplified version	1	yes
Traffic flow			Describes the generic model (1 sentence)	Describes what parameter to use and the effect of vehicle class distribution		1	yes
Speed			Describes the effect of speed on different parts of the method (1 sentence)	Describes what speed parameter to consider (average, maximum, taken from trains, etc.) and defines speed dimension	Different minimum speeds in MS are used	1	yes
Running conditions			Description of the effect of acceleration	Advice on when and how to use it, situations where it can be considered and where it should be avoided. Allows the use of solely stationary speed	Describes how to obtain the acceleration parameter	3	yes
Wheel roughness			1 sentence on what it is and the function	If it is selected, specifies what level of detail is required	Explains where to get it, how and in what format,	1	yes

Rail roughness			1 sentence on what it is and the function	If it is selected, specifies what level of detail is required	Explains where to get it, how and in what format,	1	yes
Vehicle transfer function			1 sentence on what it is and the function	Uses the one from database (depends on the choices of vehicle class) User-defined	If user-defined, explains what it is and how to get it	1	yes
Track transfer function			1 sentence on what it is and the function	Uses the one from database (depends on the choices of vehicle class) User-defined	If user-defined, explains what it is and how to get it	1	yes
Contact filter			1 sentence on what it is and the function	Uses the one from database (depends on the choices of vehicle class) User-defined	If user-defined, explains what it is and how to get it	1	yes
Impact noise			1 sentence on what it is and the function	If joint density is selected, specifies what level of detail is required Uses the table of impact roughness levels from database (depends on the choices of vehicle class) User-defined	Explains where to get it, how and in what format,	1	yes
Squeal			1 sentence on what it is and the function	If it is selected, specifies what level of detail is required and whether to use or not default values	Explains where to get it, how and in what format,. Explains how the table of reference R0 values was obtained	2	yes
Braking noise			Explains what braking noise is and where it occurs Ref. broadband braking noise Ref. brake squeal Speed dependency factor Duration correction	Explains whether or not to use it, whether to use default values or a specific correction	Explains all the details of the points above and how to get the duration correction	2	yes
Traction noise			Explains what it is	Explains possible options for introducing it (or NOT using it)	Description of possible standards and techniques to get traction noise	2	yes

Aerodynamic noise			Explains what it is and when it is common to use it	Explains possible options for introducing it (or NOT using it)	Explains how the 'α' coefficients are obtained	1	yes
Other effects			Explains what it is and when it is common to use the correction for bridge	Explains possible options for introducing it (or NOT using it)	Explains how to get the C bridge or any other correction effect	1	yes
Industrial noise source emission						1	
Source description		*A section on the issue of building radiation needs to be introduced in CNOSSOS-EU (see VDI 2571 (Germany) or EN 12354-4 (2000) transmission of indoor sound to the outside)*				1	yes
Number and position of sources						1	yes
Sound power emission						1	yes
Correction for working hours						1	yes
Source directivity						1	yes
Measurements						1	yes
Sound propagation						1	
Source segmentation						1	yes
Propagation paths						1	yes
Reflections on building façades and vertical obstacles						1	yes
Propagation							
ΔL_{geo} geometrical attenuation						1	yes
h_S source height						1	
h_R receiver height						1	
R distance source-receiver						1	yes
$\Delta\theta$ angle of view						1	yes
R_{min} shortest distance line source-receiver						1	yes
ΔL_{atm} atmospheric attenuation						1	yes

ΔL_{excess} excess attenuation						1	yes
ΔL for diffraction and reflection on ground profile						1	yes
ΔL_D diffraction attenuation						1	yes
δ signed geometrical path difference						1	yes
d_S distance source-diffraction point						1	yes
d_R distance receiver-diffraction point						1	yes
θ_S diffraction angle on source side						1	yes
θ_R diffraction angle on receiver side						1	yes
ΔL_G ground attenuation						1	yes
$\Delta L_{G,flat}$ ground attenuation						1	yes
$\Delta L_{G,valley}$ ground attenuation						1	yes
w_k modified Fresnel weights						1	yes
f_c transition frequency						1	yes
Q_k spherical-wave reflection coefficient						1	yes
D_k geometrical weighting factor						1	yes
C_k coherence factor						1	yes
R_p plane-wave reflection coefficient						1	yes
Z normalised ground impedance						1	yes
θ angle of reflection						1	yes
F_Q boundary loss factor						1	yes
C_{coh} coherence factor						1	yes
σ_{hS} standard deviation of source height						1	yes
σ_{hR} standard deviation of receiver height						1	yes
γ_T turbulence factor						1	yes
n_f Fresnel parameter						1	yes
						1	yes

						1	yes
ΔL_{scat} for scattering by atmospheric turbulence						1	yes
$\Delta L_{refl+dif}$ correction for reflection and diffraction by vertical obstacles						1	yes
$\Delta L_{special}$ correction for special cases						1	yes
Aircraft noise source emission						*To be defined*	
To be considered later							yes
7. GIS and data set specifications						1	No
8. Noise model data sets							
9. Noise level calculations						2	No
Overview of calculation process		Tutorial about 3D propagation concepts, cross-sections and path findings				2	No
Noise assessment systems		Information on how to choose the adapted software				2	No
Software system requirements						*3*	No
Test models and protocols						*3*	No
Software validation procedure						*3*	No
Calculation settings		Information on the use of the settings in the calculation software and their effects	How to test the effects of the settings and choose the relevant parameters. Will deal with DIN 45687			2	No
Calculation hardware environment		Information on network basis, different processes, etc.	More details			2	No
Pre-flight checks		General information	More details			2	No
Post-calculation checks		General information	More details			2	No

10. Measurements						1	No
Use of measurements in strategic noise mapping						1	No
Validation and calibration of strategic noise maps						1	No
Medium and long-term noise measurements						1	No
11. Post-processing & analysis							
Reporting of results						1	No
Reporting under the END						1	No
Presentation of results						1	No
Public participation						3	No
12. Reporting of results						1	No

(*) Priority 1: essential, items needed for strategic noise mapping

Priority 2: medium, items can be useful for strategic noise mapping

Priority 3: low, items can be useful for action planning only

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CHAPTER X. REVISED ELECTRONIC NOISE DATA REPORTING MECHANISM

X.1. Background

The CNOSSOS-EU methodological framework aims to improve the consistency and comparability of the noise assessments conducted by EU MS in accordance with the obligations placed on them by the Environmental Noise Directive (END). The deadlines for completing the assessments contained in the END are followed by key deadlines by which the information must be reported to the Commission. Without proper communication of the assessments to the Commission it cannot be guaranteed that a competent authority has complied with its obligation under the legislation. Therefore, the format for communicating the results of noise assessments to the Commission is the key driver for what should be derived from the assessment methods.

These noise exposure assessments, in turn, form only one part of a suite of reporting requirements placed upon the MS. In view of this, the EEA has developed a harmonised method of communicating all data-related information associated with the END. Known as the Electronic Noise Data Reporting Mechanism (ENDRM), it was published in advance of the first round reporting requirement for noise mapping in 2007 and to date it has been utilised by most EU MS and other EEA member countries to deliver noise data in accordance with the requirements of the Directive.

Use of the ENDRM not only helps to ensure MS-compliance with the END but also to assist in meeting the obligations of the INSPIRE Directive and the EC Shared Environmental Information Service (SEIS) requirements.

Much has been learnt about ENDRM during its use in the first-round reporting of source, noise maps and action plan data and improvements to its efficient operation have been identified for implementation in the context of the CNOSSOS-EU methodological framework.

X.2. Aim of the ENDRM

The ENDRM has been developed to facilitate EU MS reporting in a common format while ensuring that the reporting requirements of the END are met.

It addresses the reporting obligations set out in the END and provides reporting templates for EU MS to utilise.

The reporting requirements and corresponding templates are integrated into an organised structure of data flows, each of which details the content and timeline required for compliance with the END.

Directive 2002/49/EC requires MS to report a variety of information to the EC at the first and second round of implementation between 2005 and 2014. Thereafter, the data flows merge into a cyclical reporting obligation to be met every five years.

Details of the information to be reported, or these data flows, are set out in Table X.1.

Table X.1: *Data flows corresponding to reporting requirements of the END*

Data Flow	Summary description of information to be reported	Legally binding deadline	Updates by EU MS	END provision
DF1	Major roads, major railways, major airports and agglomerations designated by MS and involved in the first round (2007-2008)	30 June 2005	Mandatory Every 5 years	Art. 7-1
DF2	Competent bodies for strategic noise maps, action plans and data collection	18 July 2005	Possible At any time	Art. 4-2
DF3	Noise limit values in force or planned and associated information	18 July 2005	Possible At any time	Art. 5-4
DF4	Data related to strategic noise maps as listed in Annex VI for major roads, railways, airports and agglomerations involved in the first round: • Per agglomeration ≥ 250 000 inhabitants • Per major civil airport ≥ 50 000 movements/year • For overall major roads ≥ 6 million vehicles/year • For overall major railways ≥ 60 000 trains/year.	30 December 2007	Mandatory Every 5 years	Art. 10-2 Annex VI
DF5	Major roads, major railways, major airports and agglomerations designated by MS and involved in the second round (2012-2013)	31 December 2008	Possible At any time	Art. 7-2
DF6	Noise control programmes that have been carried out in the past and noise measures in place before adoption of action plans: • Per agglomeration ≥ 250 000 inhabitants • Per major civil airport ≥ 50 000 movements/year • For overall major roads ≥ 6 million vehicles/year • For overall major railways ≥ 60 000 trains/year.	18 January 2009	No update	Art. 10-2 Annex VI 1.3 & 2.3
DF7	Data related to action plans as listed in Annex VI for major roads, railways, airports and agglomerations involved in the first round + any criteria used in drawing up action plans: • Per agglomeration ≥ 250 000 inhabitants • Per major airport ≥ 50 000 movements/year • For overall major roads ≥ 6 million vehicles/year • For overall major railways ≥ 60 000 trains/year	18 January 2009	Mandatory Every 5 years	Art. 10-2 Annex VI + Art. 8-3
DF8	Data related to strategic noise maps as listed in Annex VI for major roads, railways, airports and agglomerations involved in the second round • Per agglomeration ≥ 100 000 and < 250 000 inhabitants • For overall major roads ≥ 3 million and < 6 million vehicles/year • For overall major railways ≥ 30 000 and < 60 000 trains/year.	30 December 2012	Mandatory Every 5 years	Art. 10-2 Annex VI

DF9	Noise control programmes that have been carried out in the past and noise measures in place before adoption of action plans: • Per agglomeration ≥ 100 000 and < 250 000 inhabitants • For overall major roads ≥ 3 million and < 6 million vehicles/year • For overall major railways ≥ 30 000 and < 60 000 trains/year.	18 January 2014	No update	Art. 10-2 Annex VI 1.3 & 2.3
DF10	Data related to action plans as listed in Annex VI for major roads, railways, airports and agglomerations involved in the second round + any criteria used in drawing up action plans: • Per agglomeration ≥ 100 000 and < 250 000 inhabitants • For overall major roads ≥ 3 million and < 6 million vehicles/year • For overall major railways ≥ 30 000 and < 60 000 trains/year.	18 January 2014	Mandatory Every 5 years	Art. 10-2 Annex VI + Art. 8-3

In order to facilitate EU MS reports from the national and regional level, the addition of data flow zero (DF0) enables the definition of various organisations which have reporting responsibility within the MS. DF0 sets out responsibilities, coverage and contact information for all the referenced organisations. DF0 thus defines the reporting structure in which the MS proposes to submit all subsequent reports.

X.3. ENDRM: a mechanism for common reporting

Simple reporting

A number of factors were considered during the development of the ENDRM. The main aim was to simplify the reporting for MS. This has been achieved by:

- reducing repetition through the use of relational database principles
- adopting formats which best suit the type of information to be reported
- keeping consistency of reporting format between the first and second implementation steps and beyond
- adopting formats which are in line with SEIS and INSPIRE requirements.

Reportnet

The information submitted by MS is to be collated and managed by the EEA on behalf of the EC, using the Reportnet system.

Reportnet is a system of integrated IT tools and business processes that create a shared information infrastructure optimised to support European environmental reporting.

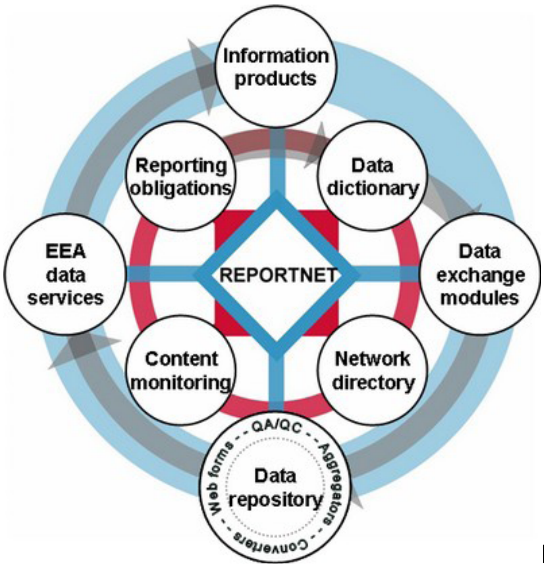

Fig. X.1: *The Reportnet system*

Reportnet provides an existing framework for the reporting of environmental data flows, including those required by directives on air quality, water and habitats. Where appropriate, data formats and specifications for the ENDRM templates have been harmonised with those of existing environmental reporting obligations reported through Reportnet.

Essentially, Reportnet is an e-reporting tool developed by the EEA in order to support this improvement in data and information flows. It is an open system that permits efficient deliveries from countries in a very transparent manner. Most importantly, Reportnet offers the ability to address data quality in two different processes.

The first process, which is being implemented data flow by data flow, is the automated quality check. During the process of uploading data to the central data repository, the deliveries are checked against the data dictionary and feedback is given to the data supplier should there be inconsistencies with the data dictionary entries.

A second quality check is applied while merging the national deliveries into a draft European data set using conversion and merging tools and before entering it into the European data warehouse (in many cases the EEA data service). At this point, the thematic experts take a close look at this draft data set. This process is conducted in conjunction with the European Topic Centre for Spatial Information and Analysis (ETC-SIA) and, if necessary, changes are suggested to the data suppliers, which may lead to a revised data delivery.

Reportnet for noise

The delivery of noise-related data through the ENDRM and Reportnet facilitates this quality checking process. If neither system is utilised by the data provider, then the quality checking process is a much more complicated task.

During the first-round reporting of noise maps in 2007, only four EEA member countries utilised Reportnet to deliver noise-related data. In October 2008 the EEA formally published guidelines for the use of Reportnet to deliver END data pertaining to Data Flow 5 for which the original deadline was at the end of that year. Following training on the use of Reportnet for noise at a workshop which took place that same month, a total of 19 countries used Reportnet to deliver data relating to Data Flow 5.

This guideline document was updated in 2010 in advance of a requirement to provide an update of Data Flow 1 in June of that year. The contents of this guidelines document will form a core element of the revised ENDRM and its associated handbook.

Through the CNOSSOS-EU project the ENDRM has been fully integrated into the Reportnet system of e-reporting, so that officially requested templates can be directly downloaded and subsequently re-uploaded by EU MS.

INSPIRE

INSPIRE is a directive for the establishment of an infrastructure for spatial information in the European Union (INSPIRE)[10].

A key objective of INSPIRE is to make more and better spatial data available for EU policy-making and the implementation of EU policies – initially environmental policy – in the MS at all levels.

Since its adoption in 2007, the INSPIRE Directive has defined the most appropriate format for data in relation to many other directives and data streams.

Relevant elements of the ENDRM have been formatted in a way that meets the requirements of INSPIRE. This includes the use of the ETRS89 geographical referencing system and the use of spatial metadata standards to accommodate delivery of noise maps, source locations, agglomeration boundaries and action planning areas, including zones delimited as quiet areas.

Importantly, the reporting formats are designed to meet a minimum achievable standard that takes into account the diversity of approaches to managing spatial data which currently exists across MS.

Reporting entities

The information required by the END has a temporal component. The data flows identified by the Reporting Mechanism and shown in Table X.1 detail a method for identifying the deadlines inherent in the Directive. It is also apparent from these data flows and from the statements in the Directive that the reporting obligations can be further sub-divided into information required by entity as follows:

- major roads
- major railways
- major airports
- agglomerations.

The reporting structure implemented in a MS may be different for each of these entities. Therefore, DF0 defines the reporting structure for each of the four entities separately. Furthermore, the END also indicates that there is a requirement for certain data flows within agglomerations to be sub-divided between the four sources:

- roads inside agglomerations
- railways inside agglomerations

[10] Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) 14.03.2007 (http://inspire.jrc.ec.europa.eu/)

- airports inside agglomerations
- industry inside agglomerations.

Figure X.2 presents the high-level design implemented for the Reporting Mechanism in terms of data pertaining to major roads. This is a sample data model reflecting both the temporal aspects of the reporting obligations represented by the individual data flow elements, and the structure of the model by entity. The relationships between all the different pieces of information required are also displayed to provide a complete overview of the structure of the ENDRM for this source. At the centre of the model is DF0, highlighting how this information is critical to the structure and understanding of the subsequent data that are to be reported.

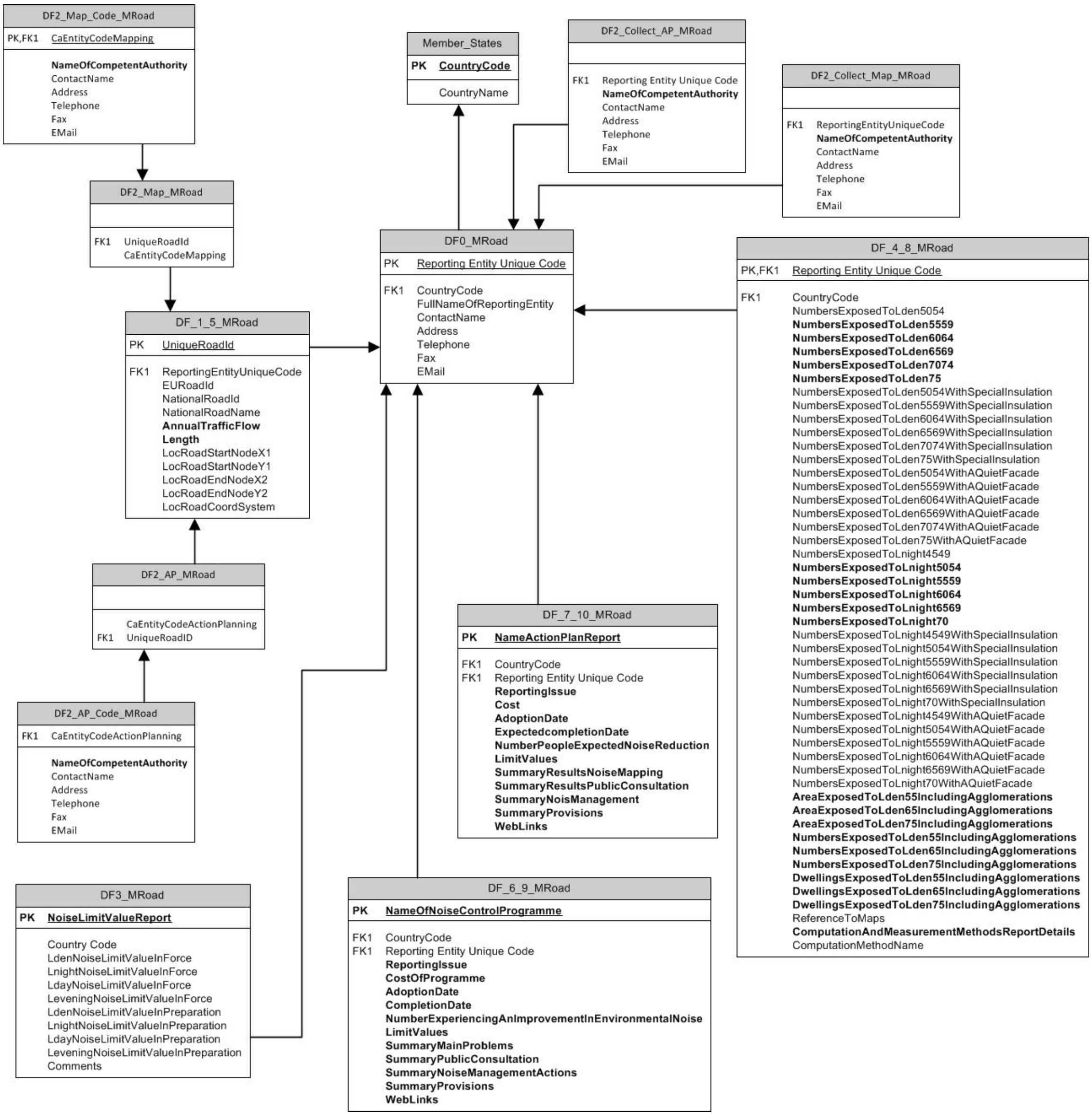

Figure X.2: *Sample ENDRM data model for major roads only*

The ENDRM and first-round strategic noise maps

The ENDRM was first presented to the Eionet National Reference Centres for Noise at a workshop hosted by EEA in Copenhagen in June 2007. Despite the positive response to its introduction and the provision of training on its use, the experience gained in processing the country data has revealed many irregularities and problems with the application of the ENDRM.

The ENDRM was initially used by 70% of countries to deliver data relating to the first round of noise maps. However, only a small fraction of these reports could be considered to be complete. This lack of completeness was identified as one of the key problems. Also identified as a recurring error was a tendency for reports to have indecipherable data. In other words, data for which the meaning is ambiguous, e.g. a number with several decimal places attributed to it. This has been attributed to a lack of clarity in the text of the Directive itself.

In other cases, some reporters considered it appropriate to amend the templates to suit their own needs, or simply to deliver the data in a completely different format, again to suit their own needs.

All in all, the problems identified have led to delays in quality assurance of the data and misinterpretation of exposure statistics. This, in turn, means that the EEA or the Commission is unable to make a fully informed and accurate assessment of the impact of noise from key sources in Europe.

X.4. The ENDRM in relation to CNOSSOS-EU

In seeking to define a common approach to noise assessment in Europe, the CNOSSOS-EU project provided an opportunity for a review of the ENDRM as the common reporting method.

This includes an evaluation of the use of ENDRM in the first round of noise mapping and implementation of the key changes that are required to ensure that the Commission gains value from the second round of reporting due in December 2012. In addition, the Commission has taken the view that the ENDRM could be proposed as a mandatory method of reporting for noise data in the future.

One driver for this is the Shared Environmental Information Service for Europe (SEIS) communication, as issued by the Commission in 2008. A key element of SEIS is the electronic delivery of data, for which task 9 of CNOSSOS-EU will ensure that the ENDRM is fully integrated into the Reportnet data management system as offered to countries as a method by which this e-reporting can be achieved.

Combined with the recent advances in health impact evidence and the introduction of stringent Night Noise Guidelines for Europe, it is necessary for the Commission to ensure that maximum value can be derived from the data reported. In other words, a full impact assessment for all sources and according to the guideline levels needs to be achieved.

CNOSSOS-EU WG 9

The process to review the ENDRM began with the establishment of a review group comprising members from the EEA, ETC-SIA, Eionet and the EEA Expert Panel on Noise (EPoN). In addition, the services of the contractor originally responsible for developing the mechanism, Extrium Ltd, were also retained.

This group held formal meetings in January 2010 and May 2010 during which the main task in relation to reviewing the ENDRM were completed. This was of course prior to the official commencement of the CNOSSOS-EU project. With the formal establishment of CNOSSOS-EU, the review group concluded its work as CNOSSOS-EU WG 9, for which a meeting was hosted by the EEA in January 2012. The membership of this working group may be found under the list of contributors at the end of this report.

It was concluded that the ENDRM has only been utilised for one round of noise data reporting and it could be that countries are still only getting used to its requirements and format. Any review of the ENDRM should be restricted to only the elements that need to change in order to improve clarity of the data and serve the new needs for a representative assessment of noise exposure across Europe.

One reason for this is that the potential for a revised Directive may introduce new reporting requirements that render the existing ENDRM redundant. Any wholesale changes to the ENDRM now may only need to be repeated in the near future. In conclusion, a more fit-for-purpose version of the current ENDRM is what can be delivered by CNOSSOS-EU.

With agreement on the types of improvements that could be implemented in the ENDRM, it only remained to fine-tune the key changes that are required to make the ENDRM fit-for-purpose in the second round of noise mapping and beyond.

Suggested revisions to the 'MS Excel' and 'MS Word' templates were tabled and agreed. The former will remain in the 'MS Excel' format but with additional desirable data requirements for global exposure assessment for all noise sources combined in agglomerations, expanded decibel banding to take account of the new night noise guidelines for Europe and the expansion of requirements to deliver data using appropriately defined GIS standards.

During 2011, the ENDRM template revisions were implemented and the data dictionary of Reportnet rewritten to accommodate these new requirements. This process involved successive rounds of trial data deliveries to Reportnet in order to test the templates and data dictionary. These trials were to be conducted by nominated data reporters from Eionet and ETC-SIA.

The revised ENDRM

Throughout the review and amendment of the ENDRM, it has been a priority to ensure that the fundamental structure of the original reporting mechanism remains the same as adopted in 2007. This will ensure continuity of reporting and subsequently assessment of noise data at European scale for each round of noise mapping and associated data deliveries.

Therefore, the improvements to the ENDRM will remain largely unnoticed by the user and MS-nominated reporters. Where the changes have been effected is in the Data Dictionary, the Central Data Repository (CDR) and also the Reporting Obligations Database (ROD) of Reportnet.

To take account of the improvements, a revised ENDRM handbook has been prepared by the

EEA. This was published in early 2012 and is the cornerstone of a training workshop provided by the EEA for all of its members and co-operating countries at the same time.

This workshop was presented as an Eionet event and was an official element of the CNOSSOS-EU project. Nevertheless, it marked the culmination of the work completed by the ENDRM review group and the CNOSSOS-EU WG 9 and represents the key interface between the assessment of noise throughout Europe and the sharing of the results by means of one common noise methodological framework (CNOSSOS-EU).

Key points to note:

- The ENDRM template structure remains the same as in 2007
- There are no new mandatory reporting requirements
- The ENDRM is Reportnet-ready
- Use of Reportnet is highly recommended by the European Commission.

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10. Night Noise Guidelines for Europe

    http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/noise/publications/2009/night-noise-guidelines-for-europe

LIST OF CONTRIBUTORS

The development of the CNOSSOS-EU methodological framework by DG JRC on behalf of DG ENV is the fruit of the contribution of and/or consultation with a wide array of noise experts from the EU MS, and close collaboration with other European Commission services, EEA, EASA and WHO-Europe. The following list of contributors pertains only to the CNOSSOS-EU Technical Committee's WGs/DTs which were activated during Phase A of the CNOSSOS-EU development. The entries in the list of contributors are colour-coded according to their affiliation or the category of expertise they belong to (see Figure I.1).

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Birger Plovsing	**DELTA Test & Consultancy, DENMARK**
Guillaume Dutilleux	**CETE de l'EST, FRANCE**
Christian Kirisits	**AUSTRIA**
Christoph Lechner	**Amt der Tiroler Landesregierung, AUSTRIA**
Panu Maijala	**VTT Technical Research Centre, FINLAND**
Matthias Hintzsche	**UBA, GERMANY**
Jirí Michalík	**Public Health Institute of Ostrava, CZECH REPUBLIC**
Lorenzo Lombardi	**Ministry of Environment, ITALY**
Giuseppe Marsico	**Ministry of Environment, ITALY**
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Dirk van Maercke	**CSTB, FRANCE**
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CNOSSOS-EU WG/DT 6 - Good practice guidelines

WG/DT 6 *facilitator, main drafter*

Simon Shilton	**ACUSTICA Ltd, UNITED KINGDOM**

WG/DT 6 *Review panel*

Kjell Strommer	**Trafikverket, Sweden**
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Thomas Werst	**EBA, GERMANY**
Christoph Lechner	**AUSTRIA**
Radosław Kucharski	**Institute for Environmental Protection, POLAND**
Pavel Junek	**Public Health Institute of Ostrava, CZECH REPUBLIC**
David Ecotière	**CETE /LRPC de Strasbourg/6 Acoustique, FRANCE**
Francis Golay	**CETE /LRPC de Strasbourg/6 Acoustique, FRANCE**
Victor Minchevici	**Minsitry for Environment & Forest, ROMANIA**
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Fabienne Anfosso	**IFSTTAR, FRANCE / former DG JRC member**
Vittorio Reina	**DG JRC, Unit I.1**
Stylianos Kephalopoulos	**DG JRC, Unit I.1**

CNOSSOS-EU WG/DT 9 – Revised Electronic Noise Data Reporting Mechanism

WG/DT 9 *facilitator, main drafter*

Colin Nugent	**European Environment Agency**
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WG/DT 9 *Review panel*

Guillaume Dutilleux	**CETE de l'EST, FRANCE**
Stephen Turner	**DEFRA, UNITED KINGDOM**
Matthias Hintzsche	**UBA, GERMANY**
Radosław Kucharski	**Institute for Environmental Protection, POLAND**
Roman Ortner	**Umweltbundesamt, AUSTRIA**
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Núria Blanes	**ETC-SIA, SPAIN**
Jaume Fons	**ETC-SIA, SPAIN**
Stylianos Kephalopoulos	**DG JRC, Unit I.1**

CNOSSOS-EU WG/DT 10 – Assigning noise levels and population to buildings

WG/DT 10 *facilitator, main drafter*

Christian Popp	**LÄRMKONTOR GmbH, GERMANY**

WG/DT 10 *Review panel*

Jose Luis Bento Coelho	**CAPS – Instituto Superior Técnico, PORTUGAL**
Konstantinos Vogiatzis	**LTEA, University of Thessaly, GREECE**
Lars Schade	**UBA, GERMANY**
Martin van den Berg	**VROM, THE NETHERLANDS**
Guillaume Dutilleux	**CETE de l'EST, FRANCE**
David Ecotière	**CETE / LRPC, FRANCE**
Francis Golay	**CETE / LRPC, FRANCE**
Simon Shilton	**ACUSTICA Ltd, UNITED KINGDOM**
Dirk van Maercke	**CSTB, FRANCE**
Gaetano Licitra	**ARPAT, ITALY**
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Mats Nilsson	**Stockholm University, SWEDEN**
Gianluca Memoli	**NPL, UK**
Dick Botteldooren	**Ghent University, BELGIUM**
Lars Find Larsen	**COWI, DENMARK**
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EEA

Colin Nugent	European Environment Agency

WHO-Europe

Rokho Kim	WHO European Centre for Environment and Health

Furthermore, a wide array of **noise experts** were involved in the discussions during and after the workshops and ad hoc meetings organised and they **contributed** to the recommendations made during the **preparatory phase** of development of CNOSSOS-EU.

1 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)
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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)
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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. Määttää (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 (Ministery VROM, The Netherlands)
H. van Leeuwen (DGMR, The Netherlands)
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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. Kephalopoulos (DG JRC, Unit I.1)
M. Paviotti (DG JRC, Unit I.1)
B. Gergely (DG ENV, Unit C.3)
C. Nugent (EEA)
W. Schneider (DG ENTR)
S. Arrowsmith (EASA)
G. Gardiol (European Railway Agency)

2 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)
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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)
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B. Gergely (DG ENV, Unit C.3)
C. Nugent (EEA)

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

W. Bartolomaeus (BASt, Germany)
M. Cerchiai (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. Kephalopoulos (DG JRC, Unit I.1)
F. Anfosso-Lédée ((DG JRC, Unit I.1)
B. Gergely (DG ENV, Unit C.3)
C. Nugent (EEA)

4 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)*
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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)
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M. Paviotti (Consultant, Italy)
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B. Gergely (DG ENV, Unit C.3)
C. Nugent *(apologies)*
K. de Vos (DG TREN) *(present only the 1st day)*
H. Vu Duc (DG TREN) *(present only the 1st day)*
S. Arrrowsmith (EASA)
W. Franken (EASA)

LIST OF ABBREVIATIONS

ANP	Aircraft Noise and Performance
APU	Auxiliary Power Unit
AzB	Anleitung zur Berechnung von Lärmschutzbereichen
CA	Competent Authority
CAEP	Committee on Aviation Environmental Protection
CDR	Central Data Repository
CIRCA	COMMUNICATION & INFORMATION RESOURCE CENTRE ADMINISTRATOR
CNOSSOS-EU	**C**ommon **NO**ise A**SS**essment meth**O**d**S** in **Eu**rope
DF	Data Flow
DG ENV	Directorate-General for the Environment
DG JRC	Directorate-General Joint Research Centre
DG MOVE	Directorate-General for Mobility and Transport
DIN	Deutsches Institut für Normung eV
DMUs	Diesel Motored Units
DT	Drafting Team
EASA	European Aviation Safety Agency
EC	European Commission
ECAC	European Civil Aviation Conference
EEA	European Environment Agency
EIONET	European Environment Information and Observation Network
END	Environmental Noise Directive (2002/49/EC)
ENDRM	Electronic Noise Data Reporting Mechanism
EMUs	Electric Motored Units
EPoN	Expert Panel on Noise
ETC-SIA	European Topic Centre for Spatial Information and Analysis
ETRS89	European Terrestrial Reference System 1989
EU	European Union
FAA	Federal Aviation Administration
GA	General Aviation
GDP	Gross Domestic Product
GIS	Geographical Information System
GML	Geography Markup Language
GPG	Good Practice Guidelines
ICAO	International Civil Aviation Organization

IEC	International Electrotechnical Commission
INM	Integrated Noise Model
INSPIRE	Infrastructure for Spatial Information in the European Community
ISO	International Organization for Standardization
MS	Member States
NOISE	Noise Observation and Information Service for Europe
NPD	Noise Power Distance
NRC	Noise Regulatory Committee
ROD	Reporting Obligations Database
SEIS	Shared Environmental Information Service
TC	Technical Committee
US FAA	US Federal Aviation Administration
VBEB	Vorläufige Berechnungsmethode zur Ermittlung der Belastetenzahlen durch Umgebungslärm
WG	Working Group
WG-AEN	Working Group Assessment of Exposure to Noise
WHO	World Health Organization
XML	EXtensible Markup Language

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Abstract

In accordance with Article 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 DG ENV's Noise Regulatory 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).

The CNOSSOS-EU methodological framework described in 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, 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.

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