Bonneagar Iompair Éireann
Transport Infrastructure Ireland

TII Publications

GE PE DN CC OP AM RE

Common Noise Assessment Methods in Europe (CNOSSOS-EU): Interim Road Surface Correction Factors for National Roads in Ireland

RE-ENV-07006
October 2022

RE Research

Technical

About TII

Transport Infrastructure Ireland (TII) is responsible for managing and improving the country's national road and light rail networks.

About TII Publications

TII maintains an online suite of technical publications, which is managed through the TII Publications website. The contents of TII Publications is clearly split into 'Standards' and 'Technical' documentation. All documentation for implementation on TII schemes is collectively referred to as TII Publications (Standards), and all other documentation within the system is collectively referred to as TII Publications (Technical).

Document Attributes

Each document within TII Publications has a range of attributes associated with it, which allows for efficient access and retrieval of the document from the website. These attributes are also contained on the inside cover of each current document, for reference.

TII Publication Title	*Common Noise Assessment Methods in Europe (CNOSSOS-EU): Interim Road Surface Correction Factors for National Roads in Ireland*
TII Publication Number	*RE-ENV-07006*

Activity	*Research (RE)*		**Document Set**	*Technical*
Stream	*Environment (ENV)*		**Publication Date**	*October 2022*
Document Number	*07006*		**Historical Reference**	**N/A**

TII Publications Website

This document is part of the TII publications system all of which is available free of charge at http://www.tiipublications.ie. For more information on the TII Publications system or to access further TII Publications documentation, please refer to the TII Publications website.

TII Authorisation and Contact Details

This document has been authorised by the Director of Professional Services, Transport Infrastructure Ireland. For any further guidance on the TII Publications system, please contact the following:

Contact:	Standards and Research Section, Transport Infrastructure Ireland
Postal Address:	Parkgate Business Centre, Parkgate Street, Dublin 8, D08 DK10
Telephone:	+353 1 646 3600
Email:	infoPUBS@tii.ie

TII Publications

Activity:	Research (RE)
Stream:	Environment (ENV)
TII Publication Title:	Common Noise Assessment Methods in Europe (CNOSSOS-EU): Interim Road Surface Correction Factors for National Roads in Ireland
TII Publication Number:	RE-ENV-07006
Publication Date:	October 2022
Set:	Technical

Contents

Contents

1. Introduction

1.1 Noise Mapping with CNOSSOS-EU

The Environmental Noise Directive (END) [8] requires that all EU Member States prepare strategic noise maps every five years. For road traffic noise, this includes developing strategic noise maps for all major roads (> 3 million vehicles per year) in Ireland, as well as noise maps for all roads inside agglomeration areas. Annex II of the END sets out the calculation methods which are to be used. For the upcoming fourth round of noise mapping, Annex II has been revised by the mandatory EU directive 2015/996 [4], which describes the common noise assessment methods for Europe, commonly known as “CNOSSOS-EU”. Directive 2015/996 has recently been amended by delegated directive 2021/1226 [5], providing new noise emission factors and road surface corrections, among other revisions.

The CNOSSOS-EU road traffic noise emission model calculates rolling and propulsion noise for different vehicle categories as a function of speed and frequency. The emission is initially calculated under reference conditions, then corrected for differing situations. CNOSSOS-EU comes with a set of tables containing default coefficients A and B (‘emission factors’) that represent the noise level of the average EU vehicle fleet, under reference conditions, as a function of speed. These coefficients are set out in Appendix F, Table F-1, of Directive 2021/1226 for different vehicle categories (light, medium, heavy, mopeds/motorcycles) and are based on pass-by measurements performed at several EU locations during the IMAGINE project 15 years ago [15]. The definition of the reference conditions includes air temperature, constant speed, flat roads, and a reference road surface. The latter is defined as

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

where ‘0/11’ denotes the min/max stone aggregate size, i.e., between 0 and 11 mm, which is also commonly abbreviated with just ‘11’, e.g., SMA11 for stone mastic asphalt 0/11.

For road surfaces that are not within this definition, road surface correction factors should ideally be developed, otherwise a number of default values may be used which are provided within CNOSSOS-EU Appendix F, Table F-4. Road surface correction factors are presented as a set of α’s and β’s for each surface type, which are different for each vehicle category. These are relative corrections, which express the difference between the emission on that particular surface with respect to the reference surface.

The default road surface corrections are taken from the Dutch national noise assessment method, Rmg2012, and therefore contain only surfaces that are common in the Netherlands (NL) [9]. The corrections have been developed from Statistical Pass-By (SPB) measurements (roadside pass-by measurements in line with ISO11819-1 [10]) on various pavements, which are then compared to SPB-measurements on the reference surface. The Dutch method described for developing new road surface corrections [7] also specifies that SPB-measurements are used.

To date, the Commission has not specified any method to develop new road surface correction factors, however they have commissioned CEN Technical Committee 227 Working Group 5 to develop methods for road surface acoustic labelling, including a method to develop CNOSSOS-EU correction factors. The method has not yet been formally published, but WG5 representatives have presented the draft method in various reports and conference papers. This method will be based not on SPB, but on Close Proximity (CPX) measurements (on-road trailer measurements in line with ISO11819-2 [11]).

1.2 CNOSSOS-IE Road Surface Corrections

For the implementation of CNOSSOS-EU in Ireland, which, for this report, are labelled “CNOSSOS-IE”, TII has procured AWN Consulting Ltd., aided by M+P, to develop road surface corrections for the three most common pavement types on the TII network:

- Hot Rolled Asphalt (HRA)
- Stone Mastic Asphalt 10 mm (SMA10)
- Stone Mastic Asphalt 14 mm (SMA14)

For each of these three pavements, there is no direct match in the CNOSSOS-EU database, and new correction factors should be developed. AWN Consulting Ltd. will perform a series of SPB-measurements throughout 2022 to establish a dataset with which M+P will develop the required correction factors.

The Round 4 strategic noise mapping exercise being undertaken by TII, and other Noise Mapping Bodies, will take place throughout 2022 since it is the first time the noise mapping will be performed with the new CNOSSOS-EU method. To enable initial calculations, interim road surface correction factors are being developed based on existing measurement data.

As there is currently limited SPB measurement data available for Irish road surfaces, the interim road surface correction factors will be derived from CPX data measured by M+P on Irish roads in 2019. This report summarises the method followed to derive CNOSSOS-IE road surface corrections (Chapter 2), the available CPX dataset (Chapter 3), the resulting interim road surface corrections (Chapter 4), and our conclusions and recommendations for improving these corrections (Chapter 5).

2. Methodology

2.1 Objective

The CNOSSOS-EU method calculates separate sound power levels for the rolling noise (L_{WR}) generated by the tyre/road interaction, and the propulsion noise (L_{WP}) generated by the vehicle driveline. All calculations are performed in eight 1/1-octave frequency bands, from 63 to 8000 Hz.

To these sound power levels, corrections for the influence of the road surface are calculated as follows:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_m \cdot \log_{10}\left(v_m / v_{ref}\right) \tag{1}$$

for the rolling noise, and

$$\Delta L_{WP,road,i,m} = \min\left\{\alpha_{i,m}; 0\right\} \tag{2}$$

for the propulsion noise.

where $\alpha_{\mathrm{i,m}}$ is the offset, i.e. the road surface influence at the reference driving speed v_{ref} = 70 km/h, and β_{m} is the speed coefficient, which leads to a larger or smaller road surface influence at different driving speeds. The subscript i = 1...8 indicates the frequency band and m indicates the vehicle category. Note that the speed coefficient β_{m} is independent of frequency, so this is a single scalar value per vehicle category.

The resulting $\Delta L_{WR,road,i,m}$ and $\Delta L_{WP,road,i,m}$ then express the influence of the pavement on the calculated sound power levels, relative to the reference road surface. If the road surface is equal to the reference surface, these values will be zero. Note that the $\Delta L_{WP,road,i,m}$ is always zero or negative: a different road pavement may reduce the propulsion noise but may not increase it. The assumption here is that noise reducing pavements will generally have some sound absorbing properties that will also reduce propulsion noise, where as ‘noisy’ pavements will be noisy mainly due to surface roughness which only affects the tyre/road noise.

The objective for the method described here is to develop interim road surface corrections for CNOSSOS-IE, based on CPX measurements. That is: for each relevant road surface category, the α’s and β’s will be determined from the measurement data.

2.2 Background

The CPX-based method described here is based on a draft working document of the CEN/TC227 standard Road and airfield surface characteristics – Characterisation of the acoustic properties of road surfaces. The method is under development by WG5 and is based on the research work performed in the EU 7th Framework project ROSANNE [6]. The method is intended to be primarily applied for three scenarios:

1. to define the acoustic label value of a generic or proprietary pavement type;
2. to check compliance of a pavement with the specifications for that pavement type;
3. to monitor the behaviour of the acoustic properties over the lifetime of the product.

The method also explicitly states that the procedure described *“also allows the derivation of input parameters for road surface corrections within environmental noise calculation methods (in particular, the harmonised CNOSSOS-EU method)*”. A separate chapter is dedicated to this purpose, including reference values needed to derive the relative correction factors.

The draft method only mentions the $\Delta L_{WR,road,i,m}$ correction to the rolling noise component; the influence on propulsion noise is not mentioned. In the ROSANNE D2.5 report [1], it is briefly mentioned that their experts believe equation (2) ‘*overestimates the effect of absorption on propulsion noise*’. They recommended that further investigations are made in order to check the relationship. As no such investigation is currently known to the authors, it is assumed for these interim correction factors that the $\alpha_{i,m}$ found from the method is also to be applied for the propulsion noise correction, as the CNOSSOS-EU method prescribes.

As far as M+P is aware, although a recent literature review has not been conducted, the proposed draft method has not yet been applied or tested elsewhere in Europe. Any improvements to, and deviations from, the CEN WG5 method proposed from the M+P perspective, either for data collection or for analysis, will be explicitly noted.

2.3 CPX Measurements

To establish CNOSSOS-EU road surface corrections, the CEN method requires CPX-measurements according to the ISO11819-2:2017 standard [11], with some specific requirements:

- CPX measurements must be performed with test tyre P for evaluating the road surface correction for light motor vehicles (m = 1), and with test tyre H for evaluating the correction for medium and heavy vehicles (m = 2 or 3). The test tyres are described in ISO11819-3:2021 [12].
- Measurements shall be made at different speeds with a total range of at least 30 km/h. One of the measurement speeds shall be as close as possible to the reference speed v_{ref} of 70 km/h. No speed variation tolerances are given.
- Following the CNOSSOS-EU definition, test sections should be representative of the lifetime of the road surface type, assuming proper maintenance. The CEN method advises five sections of different ages, ranging from 2 to 7 years after construction. The result is the arithmetic average of these sections. As the surface deterioration rate is different for different types of surfaces, M+P advises to differentiate the age range between surface types. ‘Old’ pavements should not have significant damage (raveling, rutting, …), and there should be an even balance between ‘old’, ‘new’ and possible ‘medium’ aged sections.
- Following ISO11819-2, CPX noise levels are measured in 1/3-octave bands from 315 Hz to 4 kHz, whereas CNOSSOS-EU requires 1/1-octave bands from 63 Hz to 8 kHz. The CEN standard mentions that if a particular CPX measurement system is able to accurately measure at frequencies above or below the ISO11819-2 prescribed range, then this data may be used. If not, the method proposes that:
  - the 250 Hz 1/1-octave band value (i = 3) is estimated from the 315 Hz 1/3-octave band by subtracting 10·log10(3);
  - the other, more extreme octave bands at 63, 125 Hz (i = 1, 2) and 8 kHz (i = 8) are set to zero.

  As stated in a 2019 paper by the CEN experts [2], these assumptions had not been validated and needed further investigation. As will be clear from the results in section 4.3, setting the correction to zero leads to an implausible spectrum shape in some cases. A different approach is therefore proposed by M+P below.

The result of the CPX measurements is an average CPX noise level $L_{\mathrm{CPXP,i,vref}}$ for tyre *P*, and $L_{\mathrm{CPXH,i,vref}}$ for tyre *H*, for each octave band i at the reference vehicle speed v_{ref} of 70 km/h. Also, from CPX measurements at different speeds, a speed coefficient b_{P} and b_{H} for tyres P and H is calculated by means of linear regression.

2.4 Reference CPX Levels

As mentioned, the CNOSSOS-EU method requires relative correction factors, expressing the difference between the surface under investigation and the reference surface. The CEN / ROSANNE researchers have collected a series of CPX measurements on SMA11 and DAC11 surfaces of medium age, leading to a CPX reference spectrum representative of the CNOSSOS-EU reference road surface [1]. The reference spectra for tyres P and H are given in Table 2.1 below. Values are given at 80 km/h typical CPX measurement speed. For the reference surface, a generic speed coefficient β of 30 dB is assumed for both P and H tyres, based upon the measurement evidence.

Table 2.1 Reference CPX Noise levels for test tyres P and H at 80 km/h (in dB)

	63Hz	125Hz	250Hz	500Hz	1 kHz	2 kHz	4 kHz	8 kHz
$L_{\mathrm{CPXPref,80}}$	-	-	77.6	87.4	97.2	92.2	83.0	-
$L_{\mathrm{CPXHref,80}}$	-	-	76.7	89.6	97.1	90.3	81.1	-

2.5 Data Analyses

For each octave band i, the coefficient $\alpha_{i,m}$ for the road surface correction is then calculated as:

$$\alpha_{WR,road,i,1} = L_{CPXP,i,vref} - L_{CPXPref,80} - 30 \cdot \log_{10}\left(v_{ref}/80\right) \tag{3}$$

for light motor vehicles (*m* = 1), and

$$\alpha_{WR,road,i,m} = L_{CPXH,i,vref} - L_{CPXHref,80} - 30 \cdot \log_{10}\left(v_{ref}/80\right) \tag{4}$$

for medium / heavy vehicles (*m* = 2 / 3),

where $L_{\mathrm{CPXP,i,vref}}$ and $L_{\mathrm{CPXH,i,vref}}$ are the CPX levels measured with tyres P and H at the CNOSSOS-EU reference speed v_{ref} = 70 km/h.

The speed coefficient β_{m} for the road surface correction is calculated from the obtained b_{P} and b_{H} speed coefficients, by calculating the difference with respect to the speed coefficient for the reference surface:

a) $\beta_1 = b_P - 30$ for light motor vehicles (*m* = 1), and
b) $\beta_m = b_H - 30$ for medium / heavy vehicles (*m* = 2 / 3).

Following a review of the dataset of available CPX measurements, M+P propose a number of modifications to be used for the data analysis:

- The analysis will be based on CPX measurements performed at both 50 and 80 km/h on each road section. This covers the required speed range of 30 km/h. Measurements at the reference speed of 70 km/h are, however, not available.
- The speed coefficients b_{P} and b_{H} could be determined by either:

  - averaging over different locations first, to find one CPX level at 50 km/h and one level at 80 km/h, and then determine the speed coefficient for that pavement type, or
  - determining a speed coefficient for each location based on the 50 and 80 km/h measurements, then averaging the speed coefficients for that pavement type.

  The method is unclear on this point; thus the latter approach is preferred, although the difference will be small.

- As no CPX measurement data is available at 70 km/h, the $\alpha_{\mathrm{i,m}}$ coefficients are determined by using a linear regression of CPXP vs. $\log_{10}(v/\,v_{\mathrm{ref}})$ based on 50 and 80 km/h measurements for each location, to find the levels at 70 km/h. These are then averaged over different locations and pavements.
- As there are fewer than five sections available for each of the pavement types under investigation, as the CEN method advises, M+P have based results on a smaller number of locations, implying a greater uncertainty in the end result.

2.6 Uncertainty

As with all modern measurement standards, the CEN method comes with a paragraph to estimate the uncertainty of the end result. It presents both a method to calculate the uncertainty, based on the standardised GUM-method [12], and a table with precalculated values. The results are also presented in a recent Internoise paper [3]. As the calculated uncertainty depends on the available measurement data, values are not presented in this report. See Chapter 4 for the uncertainty estimation of results.

3. Measurement Data

In 2019 CPX-measurements were performed at nine locations with different road surfaces, in different conditions. For each location three road sections were measured at speeds of 50 and 80 km/h. All measurements were performed with tyre P, which is representative of the acoustical behaviour of passenger cars. Tyre H, representing heavy vehicles, was not measured. An overview of the measured CPXP-level is presented in Table 3.1.

Table 3.1 Overview of road surfaces measured in 2019, with CPXP levels for 50 and 80 km/h (standard deviation in parentheses)

Location	**Surface**	**CPXP-level [dB(A)]**	
		50 km/h	**80 km/h**
1	New hot rolled asphalt	94,1 (0,2)	101,6 (0,3)
2	Old hot rolled asphalt in ‘good’ condition	95,3 (0,0)	102,8 (0)
3	Old hot rolled asphalt in ‘poor’ condition	96,3 (0,1)	103,6 (0,1)
4	SMA 14	92,2 (0,2)	99,6 (0,2)
5	Old Stone mastic asphalt 10	91,9 (0,1)	99,2 (0,2)
6	Old Stone mastic asphalt 14	94,6 (0,1)	102,0 (0,0)
7	Old porous asphalt	95,0 (0,2)	102,2 (0,1)
8	New Stone Mastic asphalt with Rubber Filler (RARX)	90,5 (0,3)	97,8 (0,3)
9	Old TSCS 14	94,9 (0,4)	102,0 (0,5)

The CPX measurement results are used for the calculation of the road surface corrections for the three most common pavement types on the TII network.

- Hot Rolled Asphalt (HRA)
- Stone Mastic Asphalt 14 mm (SMA14)
- Stone Mastic Asphalt 10 mm (SMA10)

Table 3.2 Overview of road sections, used for the determination of the road surface corrections

Asphalt Type	**Location**	**Description**
Hot Rolled Asphalt (HRA)	1, 2 and 3	Mix of new and old road sections
Stone Mastic Asphalt 14 mm (SMA14)	4, 6 and 9	Mix of new and old road sections, also results of location 9 (TCSC 14) are added.
Stone Mastic Asphalt 10 mm (SMA10)	5	Old road sections, although no data for new SMA10 are available

4. Analysis and Results

4.1 Hot Rolled Asphalt

Based on the 2019 CPX measurement results, the road surface coefficients $\alpha_{i,1}$ and β_1 have been calculated as follows.

For the calculation of the β_1, a linear regression was used between the overall CPXP-levels and the $\log_{10}(v/70)$. With CPX-levels at 50 and 80 km/h, the speed range fulfils the required range of 30 km/h. The regression line provides the value of the speed coefficient b_P.

Figure 4.1 shows the analysis for HRA (hot rolled asphalt). The value of b_P is underlined in the regression formula (= 36.3).

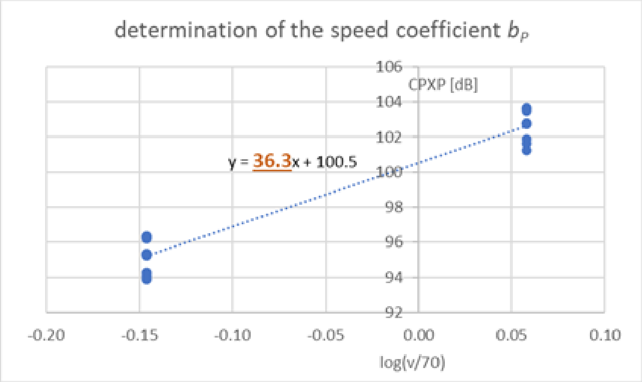

Figure 4.1 Determination of the speed coefficient bP for HRA (hot rolled asphalt)

For the calculation of the $\alpha_{i,1}$ first the CPXP values per octave must be determined at 70 km/h, for each 1/1 octave band i. This is also done by linear regression. Using the CPX-values in 1/3 octave band (315 to 5000 Hz) the CPXP-values per 1/1 octave are calculated for the octave bands 500, 1000, 2000 and 4000 Hz. The CPXP-value for the 250 Hz 1/1 octave band is based on the CPX-result in the 1/3 octave band of 315 Hz (by subtracting $10 \cdot \log_{10}(3)$).

In Figure 4.2 below, the regression analysis for HRA is presented for the five 1/1 octaves indicated. For 63 (i = 1), 125 (i = 2) and 8000 Hz (i = 8) it was not possible to determine a value based on the available CPX-results. In the regression formulas the underlined value represents the CPXP at 70 km/h.

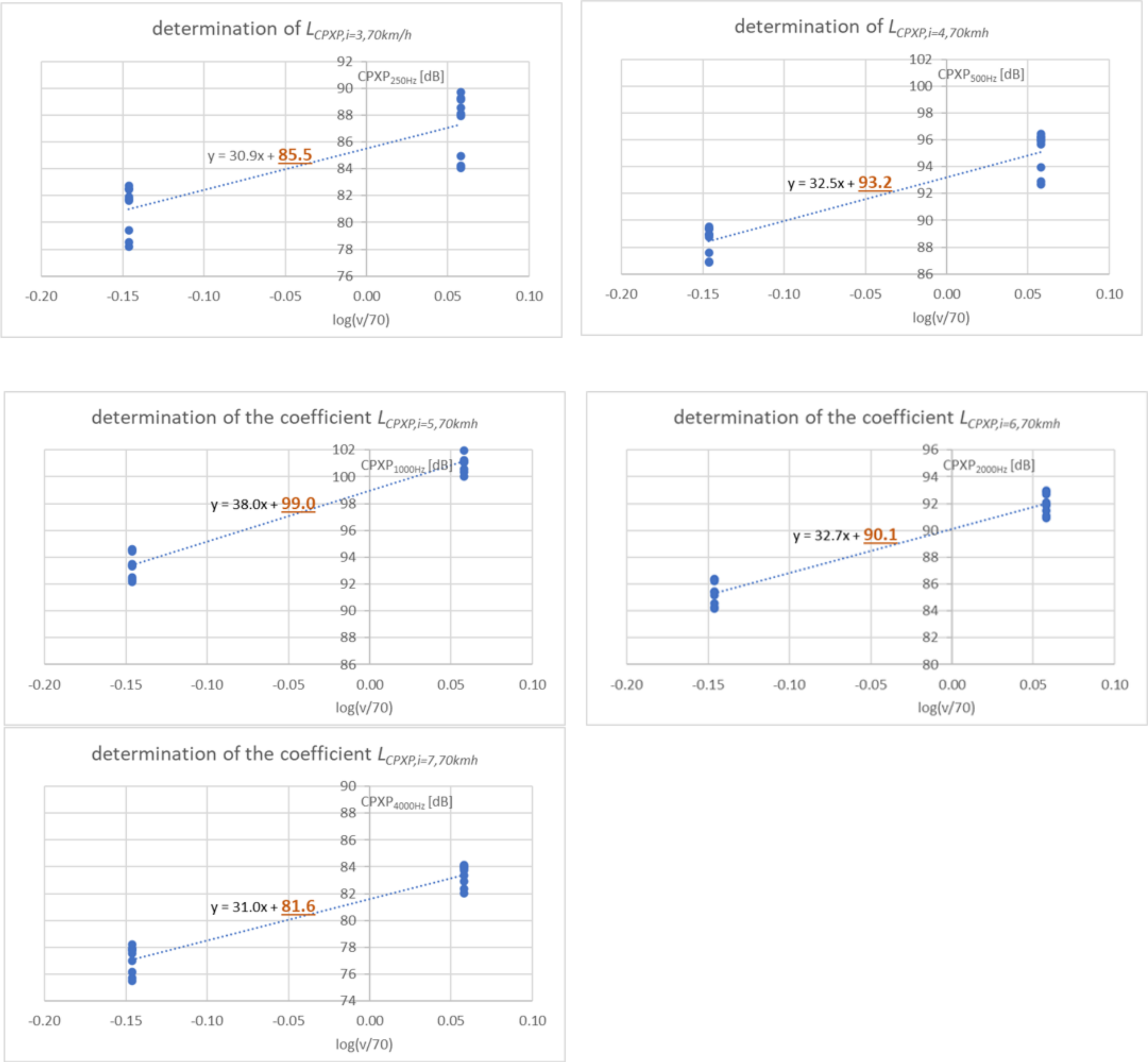

Figure 4.2 **Examples of how the $L_{CPXP,i,vref}$ was determined at 70 km/h for HRA (hot rolled asphalt)**

4.2 All Road Surfaces

For SMA 14 and SMA 10 a similar analysis as described above was performed. The results for all three surface types are presented in Table 4.1.

Table 4.1 Speed coefficient b_P and the $L_{CPXP,i,vref}$ for the different road surfaces. The reference values at 70 km/h are also shown in this table.

	$L_{CPXP,I,70km/h}$ [dB]								b_P
	63 Hz (i=1)	125 Hz (i=2)	250 Hz (i=3)	500 Hz (i=4)	1 kHz (i=5)	2 kHz (i=6)	4kHz (i=7)	8 kHz (i=8)	
HRA	-	-	85.5	93.2	99.0	90.1	81.6	-	36.3
SMA14	-	-	82.7	91.1	97.7	89.0	79.7	-	35.7
SMA10	-	-	77.0	86.6	95.6	89.7	80.7	-	35.8
$L_{CPXref,70kmh}$	-	-	75.9	85.7	95.5	90.5	81.3	-	30

It was now possible to calculate the road surface corrections α and β using equations (3) and (5). The results are shown in Table 4.2.

Table 4.2 Calculated road surface corrections αi,m and βm for light vehicles (m=1)

	A_i								β_1
	63 Hz (i=1)	125 Hz (i=2)	250 Hz (i=3)	500 Hz (i=4)	1 kHz (i=5)	2 kHz (i=6)	4kHz (i=7)	8 kHz (i=8)	
HRA	-	-	9.7	7.6	3.5	-0.4	0.3	-	6.3
SMA14	-	-	6.8	5.5	2.2	-1.5	-1.5	-	5.7
SMA10	-	-	1.2	0.9	0.1	-0.7	-0.5	-	5.8

4.3 Extreme Octave Bands

For the extreme octave bands (63, 125, 8000 Hz) it was not possible to determine road surface corrections based on the available CPX-measurements. The CEN method prescribes to set the correction value to zero. In table V it is clear that the correction in the adjacent 1/1 octave band of 250 Hz is (much) higher than zero, at least for SMA14 and HRA. It is known that at great distance from the road, or behind sound barriers, the sound levels in the lower frequency range have a more significant contribution to the overall sound level. The assumption to set these corrections to zero is therefore considered questionable, at least for any pavement with rough surface texture (more rough than the reference). There is a risk that sound levels will be underestimated in calculations when no surface corrections (α=0) are taken into account for the lowest frequencies. It is therefore proposed to equate the corrections of the lowest frequencies to the values at 250 Hz.

For the highest 1/1 octave band of 8000 Hz the CEN method can be followed and the correction will be set at zero, as Figure 4.3 indicates that this is a provides a plausible approach.

The effect of the proposed approach to determining the road surface coefficients is shown in Figure 4.3. A normalized reference spectrum for light and heavy vehicles is shown, along with the road surface corrections for HRA, with and without the proposed corrections for 63 and 125 Hz octave bands. In the graphs it is also clear that setting the corrections at 63 and 125 Hz to zero leads to an unlikely spectrum shape.

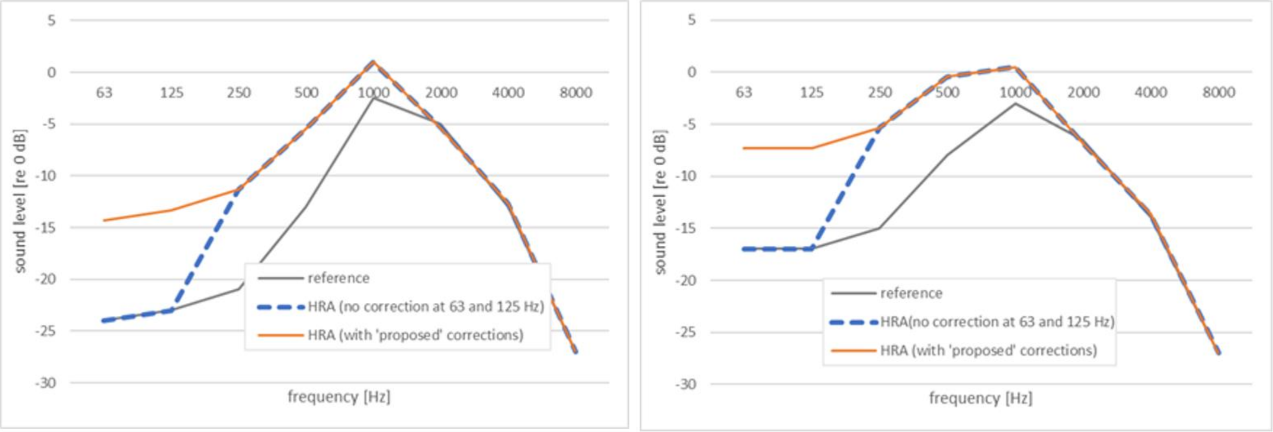

Figure 4.3 Typical traffic noise spectrum for light (top) and heavy vehicles (bottom) in a reference situation and spectra after applying the road surface corrections for HRA

5. Conclusions and Recommendations

Using the 2019 CPX measurement data available for the TII road network, the draft CEN method was followed to derive interim road surface correction factors for use with CNOSSOS-EU. The CPX data does not provide good values for the extreme octave bands (63, 125 and 8000 Hz), nor for heavy vehicles. This is a general disadvantage of the CPX method that cannot be easily solved. The SPB-surveys that are currently underway will not have this disadvantage, and will be used as the basis of the final correction factors to be developed later in the project.

The CEN methodology prescribes that the values for 63 and 125 Hz are set to zero. Here it is proposed that the corrections for these octave bands equate to the values calculated for the 250 Hz 1/1-octave band. For the 8000 Hz 1/1-octave band, we propose to follow the CEN method and set the value to zero.

For heavy vehicles we propose to use the same coefficients as used for light vehicles.

Table 5.1 Determined road surface corrections αi,m and βm for light and heavy vehicles (m=1..3)

	A_i								β_1
	63 Hz (i=1)	**125 Hz (i=2)**	**250 Hz (i=3)**	**500 Hz (i=4)**	**1 kHz (i=5)**	**2 kHz (i=6)**	**4kHz (i=7)**	**8 kHz (i=8)**	
HRA	9.7	9.7	9.7	7.6	3.5	-0.4	0.3	-	6.3
SMA14	6.8	6.8	6.8	5.5	2.2	-1.5	-1.5	-	5.7
SMA10	1.2	1.2	1.2	0.9	0.1	-0.7	-0.5	-	5.8

6. References

1. Anfosso-Lédée F. et al., Report on the compatibility of the proposed noise characterization procedure with CNOSSOS-EU and national calculation methods, Deliverable D2.5 of the ROSANNE project (www.rosanne-project.eu), 30 September 2016 - link
2. Anfosso-Lédée F., Goubert L., The determination of road surface corrections for CNOSSOS-EU model for the emission of road traffic noise, proceedings ICA2019 Aachen, pp. 3603-3610, September 2019 - link
3. Blokland G.J., Goubert L., Uncertainty in the standardized method “Characterization of the acoustic properties of road surfaces” by CEN TC227 WG5, proceedings Internoise 2021 Washington, DC, August 2021
4. Commission Directive (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council, OJEU L 168 of July 2015 - link
5. Commission Delegated Directive (EU) 2021/1226 of 21 December 2020 amending, for the purposes of adapting to scientific and technical progress, Annex II to Directive 2002/49/EC of the European Parliament and of the Council as regards common noise assessment methods, 21.12.2020, C/2020/9101 - link
6. Conter M. et al., Report on the development of the procedure for characterisation of noise properties of road surfaces including the updated draft standard, Deliverable D2.6 of the ROSANNE project (www.rosanne-project.eu), 18 December 2016 - link
7. CROW, De wegdekcorrectie voor geluid van wegverkeer 2012, publication 316, CROW knowledge platform, Ede (NL), September 2012, with errata June 2014 - link
8. Directive 2002/49/EC of the European Parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise, or: the Environmental Noise Directive (END) (2002) - link
9. https://www.infomil.nl/onderwerpen/geluid/regelgeving/wet-geluidhinder/wegverkeerslawaai/akoestisch-rapport/cwegdek/
10. ISO 11819-1:1997, Acoustics -- Measurement of the influence of road surfaces on traffic noise -- Part 1: Statistical Pass-By method - link
11. ISO 11819-2:2017, Acoustics -- Measurement of the influence of road surfaces on traffic noise -- Part 2: The close-proximity method – link
12. ISO/IEC GUIDE 98-3:2008, Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) - link
13. ISO/TS 11819-3:2021, Acoustics — Measurement of the influence of road surfaces on traffic noise — Part 3: Reference tyres – link
14. Peeters B. et al., CNOSSOS-EU: adaptations to road surface corrections, M+P report M+P.RIVM.17.03.3, revision 1, prepared for RIVM, 14 November 2017
15. Peeters B., van Blokland G.J., IMAGINE The Noise Emission Model for European Road Traffic, Deliverable 11, IMA55TR-060821-MP10, January 2007 - link
16. Tollenaar C., Mertens M., CPX-measurements on 27 road sections in Ireland (DRAFT), M+P report M+P.M50CL.19.01.1_Draft, prepared for M50 Concession Ltd., 5 April 2019

17. UNECE, Revised proposal for a draft Resolution on road surface labelling, prepared for UNECE Working Party on Noise, 69th session, ECE/TRANS/WP.29/GRB/2019/2, Geneva, January 2019 – link

Bonneagar Iompair Éireann
Transport Infrastructure Ireland

Ionad Ghnó Gheata na Páirce,
Stráid Gheata na Páirce,
Baile Átha Cliath 8, D08 DK10, Éire

www.tii.ie

+353 (01) 646 3600

Parkgate Business Centre,
Parkgate Street,
Dublin 8, D08 DK10, Ireland

info@tii.ie

+353 (01) 646 3601