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Determination of Irish Road Surface Correction Factors for CNOSSOS

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GE General

Technical

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TII Publications

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1. Introduction

1.1 Background

Transport Infrastructure Ireland (TII) is a state agency in the Republic of Ireland. The primary function of TII is to provide an integrated approach to the future development and operation of the national roads network and light rail infrastructure throughout Ireland.

Directive 2002/49/EC (commonly referred to as the Environmental Noise Directive 'the END') relates to the assessment and management of environmental noise. It is the main instrument of the European Union (EU) to quantify noise pollution levels, and trigger action within both Member States and at EU level. The END has the aim of establishing a common approach to the management of noise within the EU.

The aim of the END is to:

> *"… define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise."*

The END focusses on three action areas:

- The determination of exposure to environmental noise;
- Ensuring that information on environmental noise and its effects is made available to the public; and
- Preventing and reducing environmental noise where necessary and preserving environmental noise quality where it is good.

The Environmental Noise Regulations 2018 (ENR)[1] (as amended)[2] gives effect to the END in Irish law. The ENR designate the Environmental Protection Agency (EPA) as the National Authority for the purposes of the Regulations. EPA's role includes supervisory, advisory and coordination functions in relation to both noise mapping and action planning, as well as reporting requirements for the purpose of the END.

Under the ENR, the National Roads Authority (now TII) are designated as the Noise Mapping Body (NMB) responsible for the development of strategic noise maps for all national roads carrying in excess of 3 million vehicles a year. The relevant local authority is responsible for the development of strategic noise maps for non-national major roads. Under the ENR, TII are also the NMB for Luas light rail services in Dublin.

In accordance with the ENR, the first three rounds of strategic noise mapping (2007, 2012 and 2017) in Ireland were undertaken using an 'interim' method. The 'interim' method selected for these rounds was the Calculation of Road Traffic Noise (CRTN, 1988). However, under the END, a common noise assessment methodology has been developed and is now required for the preparation of strategic noise maps going forward, commencing with the fourth round (2022).

Commission Directive (EU) 2015/996 replaces Annex II of the END and describes the common noise assessment methodology for the END. The Directive describes a methodology for the calculation for noise from roads, railway, industry and aircraft.

[1] S.I. No. 549 of 2018 – European Communities (Environmental Noise) Regulations 2018 [online]. Available at: https://www.irishstatutebook.ie/eli/2018/si/549/made/en/pdf (accessed 10 May 2024)
[2] S.I. No. 663/2021 - European Communities (Environmental Noise) (Amendment) Regulations 2021 [online]. Available at: https://www.irishstatutebook.ie/eli/2021/si/663/made/en/pdf (accessed 10 May 2024)

Directive 2015/996 has since been subsequently amended by a Corrigenda in January 2018, and a Commission Delegated Directive in December 2020. This assessment method is referred to as CNOSSOS-EU:2020.

1.2 Road Surface Corrections in CNOSSOS-EU:2020

The CNOSSOS-EU:2020 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:2020 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 [12][3]. 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:2020 Appendix F, Table F-4. Road surface correction factors are presented as a set of variables (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) [6]. The corrections have been developed from SPB-measurements (roadside pass-by measurements in line with ISO11819-1:1997 [7]) on various pavements, which are then compared to SPB-measurements on the reference surface. The Dutch method described for developing new road surface corrections [4] also specifies that SPB-measurements are used.

1.3 Methodology

For the implementation of CNOSSOS-EU:2020 in Ireland, referred to as "CNOSSOS-IE", TII has procured AWN Consulting Ltd, aided by M+P (NL), to develop road surface corrections for at least the three most common pavement types on the TII network for new and medium age surfaces:

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

[3] References are sorted by author alphabetically in the References section, therefore numbers are not in sequence throughout the text.

For each of these three pavements, there is no direct match in the CNOSSOS-EU:2020 database, and new correction factors should be developed. AWN Consulting Ltd have performed a series of SPB-measurements in 2022 to establish a dataset with which M+P used to develop the required correction factors.

1.4 Content of this Report

This report summarises the CNOSSOS-EU:2020 calculation method (Chapter 2), the measurements taken on Irish roads (Chapter 3), the resulting road surface corrections (Chapter 4), and the conclusions and recommendations for using the road surface corrections (Chapter 5).

2. CNOSSOS-EU

2.1 Background

The calculation methodology described in Directive 2015/996 [1] was developed through a process led by DG Joint Research Centre (DG JRC) between March 2009 and the final report published in August 2012. The methodology was developed within a series of Working Groups, including nearly 150 experts from across Europe. The Common Noise Assessment Methods in Europe (CNOSSOS-EU) methods were then implemented in software, tested and prepared as a Directive between 2013 and 2015.

Since Directive 2015/996 was published, there have been two official amendments made to the Directive:

- Corrigendum to Commission Directive (EU) 2015/996, OJ L168 of 1st July 2015, L5/35 to L5/46 [3];
- Commission Delegated Directive (EU) 2021/1226 of 21 December 2020 amending, for the purpose of adapting to scientific and technical progress, Annex II of Directive 2002/49/EC of the European Parliament and the Council as regards common noise assessment methods, OJEU L269/65 of 28.7.2021 [2].

The consolidated version is referred to within this report as “CNOSSOS-EU:2020”.

2.2 CNOSSOS-EU:2020 General Structure

The CNOSSOS-EU:2020 method consists of separate modelling parts, see Figure 2.1.

- There are separate emission models for road, rail, industry and aircraft noise, which describe the sound power emitted by the source as a function of vehicle or source type, traffic intensity and composition, operating conditions and local characteristics (e.g., pavement or track type). The road noise emission model is described further in Section 2.3 below.
- The propagation model for road, rail and industry noise is derived from the French NMPB 2008 model. It specifies the attenuation of sound between the source and the receiver due to the distance, air absorption, terrain heights, reflections and diffraction from barriers and buildings, and the influence of the ground depending on its composition. Typical for the CNOSSOS-EU:2020 propagation model is the calculation of two meteorological scenarios, for homogeneous conditions (straight ray paths) and favourable conditions (downward curved ray paths), the results of which are combined with a location-specific fraction based on the occurrence of favourable propagation. Meteorological correction factors for Ireland have been derived by Noise Consultants Limited and Acustica and published in TII publication RE-ENV-07007 [14].
- For the receivers, it is specified how the area exposed to noise should be assessed from receiver grids, how the receiver points should be placed on the dwelling façades, and how the number of people in buildings and dwellings should be attributed to the calculated façade noise levels (L_{den} and L_{night}).

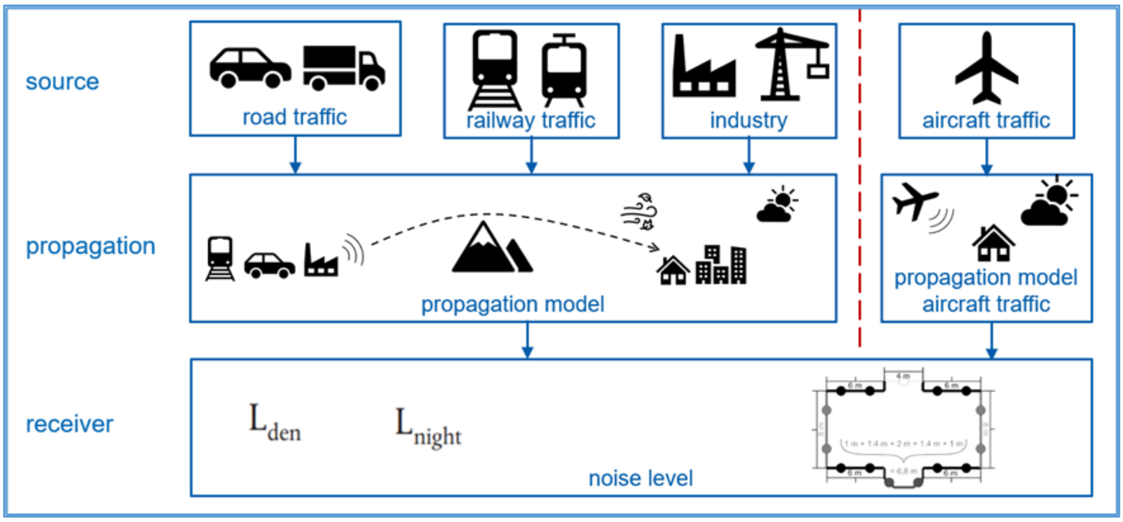

Figure 2.1 - CNOSSOS-EU:2020: emission, propagation and receiver modelling parts for different sources

2.3 Road Noise Emission Model

2.3.1 Rolling and Propulsion Noise Description

The road traffic source model calculates the noise emissions for rolling noise $L_{WR,i,m}$ and propulsion noise $L_{WP,i,m}$, for vehicle category *m* in octave band *i*, as a function of vehicle speed v:

$$L_{WR,i,m} = A_{R,i,m} + B_{R,i,m} \cdot \log_{10}\left(\frac{v}{v_{ref}}\right) + \Delta L_{WR,i,m} \tag{1}$$

$$L_{WP,i,m} = A_{P,i,m} + B_{P,i,m} \cdot \frac{v - v_{ref}}{v_{ref}} + \Delta L_{WP,i,m} \tag{2}$$

These equations involve four sets of coefficients: A_R and B_R for rolling noise and A_P and B_P for propulsion noise, with subscripts *m* and *i* defined as above. These determine the actual noise emissions for that vehicle category under reference conditions (see 2.3.2). Default values for these coefficients are given in Appendix F of Directive 2015/996, modified by Directive 2021/1225, for vehicle categories 1 (light motor vehicles), 2 (medium heavy vehicles), 3 (heavy duty vehicles), 4a (mopeds/scooters) and 4b (motorcycles), see Table 2.1 overleaf. Noise emissions for rolling and propulsion noise are added to a single source height at 5 cm above the road.

The terms $\Delta L_{WR,i,m}$ and $\Delta L_{WP,i,m}$ each describe a sum of correction factors, to be applied for situations deviating from the reference conditions, see 2.3.2.

Table 2.1 - CNOSSOS-EU:2020 Vehicle Class Definition (from [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, motorhomes, 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	Two-, Three- and Four-wheel Mopeds	L1, L2, L6
		4b	Motorcycles with and without sidecars, Tricycles and Quadricycles	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 establishing a framework for the approval of motor vehicles and their trailers, and of systems, components and separate technical units intended for such vehicles (OJ L 263, 9.10.2007, p. 1).
(2) Sport Utility Vehicles.
(3) Multi-Purpose Vehicles.

The speed range for the emission model is not limited: Directive 2015/996 states that for speeds less than 20 km/h it shall have the same sound power level as defined by the formula for v = 20 km/h. In the high-speed range, the model should be considered to be valid up to 140 km/h. At higher speeds, aerodynamic noise becomes increasingly important and may lead to a steeper increase of noise with speed than resulting from the model.

2.3.2 Reference Conditions

The source equations and coefficients are valid for the following reference conditions:

- a constant vehicle speed;
- a flat road;
- an air temperature τ_{ref} = 20 °C;
- a dry road surface;
- no studded tyres; and
- a virtual reference road surface, consisting of an average of dense asphalt concrete 0/11 and stone mastic asphalt (SMA) 0/11, between 2 and 7 years old and in a representative maintenance condition.

Whilst it is not specified within the Directive, the road traffic emission model is derived from the model output from the IMAGINE project [12] which additionally specified that the reference conditions included:

- a vehicle fleet representing the average of vehicles over the whole of Europe;
- 187mm tyre width for Category 1;
- 19% diesel for Category 1;

- 10.5% delivery vans in Category 1;
- no studded tyres;
- 4 axles for Category 3;
- 35% IRESS (illegal replacement exhausts) for Category 4, 1% for other categories; and
- a sound reflecting surface under the vehicle and in the area close to the vehicle, where the first reflection takes place; the modified reflection by absorbing road surfaces is included in the correction effect for the road surface.

The IMAGINE project proposed a series of 'regional corrections' that could be used if the vehicle fleet was different from the European average. These corrections were not in the form of correction values defined per region, but in the form of further correction formulas that need statistical parameters as input. For instance, if the percentage of diesel vs. petrol engines is known to be different in Ireland than the EU average (19%), a correction formula is available which uses the Irish percentage as input. The regional corrections proposed within the IMAGINE model were not reproduced within the CNOSSOS-EU:2020 model. This was to simplify the requirements for the purposes of strategic noise mapping and they are not used in this report. The existence of such corrections, however, supports the fact that Irish specific rolling and propulsion coefficients, and surface corrections, would be appropriate for application of the CNOSSOS-EU:2020 methodology in Ireland.

To calculate the road traffic sound power emission levels for situations deviating from the reference conditions, the correction factors included within the CNOSSOS-EU:2020 methodology are to be applied. These correction factors are given by the $\Delta L_{WR,i,m}$ and $\Delta L_{WP,i,m}$ terms in equations (1) and (2) and are defined by:

$$\Delta L_{WR,i.m} = \Delta L_{WR,road,i,m} + \Delta L_{studdedtyres,i,m} + \Delta L_{WR,acc,i,m} + \Delta L_{W,temp} \tag{3}$$

$$\Delta L_{WP,i.m} = \Delta L_{WP,road,i,m} + \Delta L_{WP,grad,i,m} + \Delta L_{WP,acc,i,m} \tag{4}$$

In addition to the road surface corrections $\Delta L_{WR,road,i,m}$ and $\Delta L_{WP,road,i,m}$, which are explained in 2.3.3 below, there are corrections for:

- $\Delta L_{WR,ac,i,m}$ and $\Delta L_{WP,acc,i,m}$: acceleration/deceleration at traffic light controlled crossings and roundabout junctions, using junction type specific coefficients per vehicle category, depending on the distance x to the intersection. The correction is zero for distances ≥ 100 meters;
- $\Delta L_{WP,grad,i,m}$: road gradients, as a function of the slope up or downwards in %, the vehicle category and the vehicle speed;
- $\Delta L_{studdedtyres,i,m}$: studded tyres (not relevant for Ireland); and
- $\Delta L_{W,temp}$: air temperature, as an average value over the whole year.

2.3.3 Road Surface Correction Factors

The *A* and *B* coefficients in equations (1) and (2) represent the sound power emission level for each vehicle category under reference conditions. For road surfaces other than the reference road surface, the CNOSSOS-EU:2020 model defines the road surface corrections for rolling noise ($\Delta L_{WR,road}$) and propulsion noise ($\Delta L_{WP,road}$) as:

$$\Delta L_{WR,road,i,m} = \alpha_{i,m} + \beta_m \cdot \log_{10}(v_m/v_{ref}) \tag{5}$$

$$\Delta L_{WP,road,i,m} = \min\{\alpha_{i,m}; 0\} \tag{6}$$

for vehicle category *m* and octave band *i*. The road surface correction coefficients $\alpha_{i,m}$ and β_m must be established for each road surface type different from the reference road surface. Tabulated values are provided in CNOSSOS-EU:2020 Appendix F, Table F-4.

The coefficients differ for each vehicle category: light, medium, heavy vehicles. For powered two-wheelers (4a/4b) corrections are zero. The Appendix F values were established with a method primarily based on the Dutch C_{wegdek} method [4] for determining road surface corrections for the Dutch national noise assessment method, Rmg2012, which in turn is based on the ISO11819-1 Statistical Pass-By (SPB) method [8]. The C_{wegdek} method was translated for the UNECE draft resolution on road surface labelling [16] and is also described in a previous study for DEFRA UK [13]. It is available as Appendix E to this report.

The noise characteristics of road surfaces vary with age and the level of maintenance, with a tendency to become louder over time. The road surface parameters are derived to be representative for the acoustic performance of the road surface type averaged over its representative lifetime and assuming proper maintenance. The same applies to the emission factors under reference conditions, as is expressed in the definition of the reference surface.

In CNOSSOS-EU:2020, corrections are provided for the following pavement types. For each pavement type, a description is given with the speed range in which it is considered valid. Table 2.2 below provides an indication of the correction for the road surface types provided with CNOSSOS-EU:2020, calculated as an overall dB(A) correction. Vehicle speeds were 80 km/h for light vehicles and 70 km/h for medium heavy and heavy vehicles, except for paving blocks where 50 km/h is used for all three vehicles categories. Mixed traffic is defined here as 85% light, 7.5% medium heavy vehicles and 7.5% heavy vehicles.

Table 2.2 - Road Surface Types for which Correction Factors are given in CNOSSOS-EU:2020

Description	Valid speed range [km/h]		Approximate correction [dB(A)]		
in brackets: upper layer chipping size	min	max	light vehicles 80 km/h	medium / heavy 70 km/h	mixed traffic
reference surface	-	-	-	-	0.0
1-layer porous asphalt concrete (11-16 mm)	50	130	-1.4	-3.1	-2.0
2-layer porous asphalt concrete (8 mm)	50	130	-4.5	-5.2	-4.8
2-layer porous asphalt concrete (5 mm)	80	130	-6.5	-5.3	-6.0
stone mastic asphalt (5 mm)	40	80	-1.9	0.0	-1.1
stone mastic asphalt (8 mm)	40	80	-0.8	0.0	-0.5
brushed concrete	70	120	+1.9	-0.3	+1.2
optimised brushed concrete	70	80	+0.3	-1.6	-0.3
fine broomed concrete	70	120	+2.0	+1.7	+1.9
chip seal / surface dressing	50	130	+2.9	-0.5	+1.9

Description	**Valid speed range [km/h]**		**Approximate correction [dB(A)]**		
in brackets: upper layer chipping size	**min**	**max**	**light vehicles** **80 km/h**	**medium / heavy** **70 km/h**	**mixed traffic**
paving blocks (herringbone)	30	60	+1.9	+3.1	+2.6
paving blocks (not herringbone)	30	60	+5.5	+6.5	+6.1
quiet paving blocks	30	60	-1.7	+1.4	+0.3
thin layer porous asphalt (8 mm)	40	130	-3.4	-1.3	-2.5
thin layer porous asphalt (5 mm)	40	130	-5.0	-1.3	-3.2

3. Measurements

3.1 Measurement Methods

Within the International Standardization Organization (ISO) two methods are available to determine the rolling noise or vehicle noise on different road surfaces:

- Statistical Pass-By method (SPB-method) according to ISO 11819-1:1997 [7]
- Close Proximity method (CPX-method) according to ISO 11819-2:2017 [8]

Both methods are used in this research to determine the acoustical properties of the different road surface types.

3.1.1 SPB-Method

ISO 11819-1 described the Statistical Pass-By method (SPB). The SPB-method is a measurement procedure, specifically designed to compare traffic noise on different road surfaces for various compositions of road traffic for the purpose of evaluating different road surface types. The method applies to traffic driving at constant speed. Microphones are placed at 7.5 m from the centre of the driving lane and at a height of 3.0 m and at 1.2 m.

Figure 3.1 - SPB-measurement set-up

For each vehicle that passes the maximum A-weighted sound level, and the vehicle speed are registered simultaneously. The results are processed in a scatter diagram in which the maximum sound level is depicted as a function of the logarithm of the speed. A best-fitting linear function follows from this scatter diagram. Vehicles that show an unrepresentative behaviour (like braking) are not included. Also pass-by’s with a high background noise level (like other passing vehicles) are excluded.

The SPB-method yields an absolute value for the noise level. However, this value is only valid around the location of the measurement. Therefore, multiple SPB measurements are taken for each road surface type to determine a representative noise level for each surface.

3.1.1.1 Correction

In accordance with the methodology outlined in ISO 11819-1 a correction is applied to the SPB-measurements. This correction is described in more detail below.

Air Temperature

The measured sound levels shall be corrected to the reference air temperature of 20°C.

A temperature correction of 0.05 dB/°C is used for cars, and a correction of 0.03 dB/°C is used for heavy vehicles, following ISO11819-1. The correction is based on the average air temperature during the measurement. The SPB measurement software used for the measurements reminds the operator to measure and enter a new air temperature value every 15 minutes. The air temperature nearest in time is assigned to each individual pass-by, and the average temperature is then calculated as an average over all pass-by temperature values. The correction calculated from the average is applied equally over all frequency bands and the total dB(A) levels.

3.1.1.2 Quality Assurance

The equipment that is used meets the requirements of type 1 according to IEC 61672-1 (microphones) and class 1 according to IEC 60942 (calibrators).

In the Netherlands, an international round robin test to compare SPB measurement systems and results between parties is organised regularly, every one to two years, by a Dutch knowledge centre on infrastructure and mobility (CROW). M+P participated in all their SPB round robin tests, most recently in 2020 [19].

3.1.2 CPX-Method

By using the Close-Proximity (CPX) method according to ISO 11819-2 the sound level close to the tyre is measured with two microphones over the length of a road section. The CPX-measurement is performed in both wheel tracks simultaneously. At the same time the vehicle speed is measured. The reference tyres and microphones are mounted in a trailer. Figure 3.2 shows a picture of the M+P CPX-trailer.

Figure 3.2 - The M+P CPX-trailer during a measurement

The CPX-measurements are performed with two different standard tyres according to ISO/TS 11819-3 [9], P1 and H1 (see Figure 3.2). The P1 tyre is called the Standard Reference Test Tyre (SRTT) and is a Uniroyal Tigerpaw 225/60 R16. This tyre is representative for the tyre/road noise of passenger cars. Results of the measurements with the P1 tyre are presented as CPX_P. The H1 tyre is an AVON Supervan AV4 195R14C. It is representative for the tyre/road noise of heavy-duty vehicles. Results of the measurements with the H1 tyre are presented as CPX_H. The applicability of CPX_H is discussed in the measurement results and analysis sections below.

Figure 3.3 - CPX-tyres according to ISO/TS 11819-3: P1 (left: Uniroyal Tigerpaw 225/60 R16) & H1 (right: Avon Supervan AV4 195R14C)

3.1.2.1 Corrections

Corrections are applied to the CPX-measurement results in accordance with ISO 11819-2. These corrections are described in more detail below.

Speed

The measurements have been performed at the reference speed of 80 km/h. The measurement results have been corrected for the actual speed with C_v according to:

$$C_v = -b \cdot \log_{10}\left(v/v_{ref}\right) \tag{7}$$

with:

C_v : speed correction [dB(A)]

b : speed constant [dB(A)]

v : actual speed [km/h]

v_{ref} : reference speed [km/h]

Tyre Tread Hardness

With the aging of the tyres, the hardness of the rubber increases. To limit this increase as much as possible, the measuring tyres of M+P are stored in a temperature conditioned room under dry atmospheric conditions at an average temperature between 0°C and 5 °C. The hardness of the measuring tyres is frequently measured and monitored. Deviations from the reference hardness are corrected according to ISO/TS 11819-3 [9].

CPX-Trailer

The measurements are performed with a CPX-trailer with enclosure. The influence of the enclosure is determined each year according to the method in ISO 11819-2. On the measurement results a device correction ($C_{d,f}$) is applied per 1/3-octave band for the influence of the enclosure.

Air Temperature

Available information suggests that the noise-temperature relation depends on the tyre and road surface and that a correction to a nominal reference value is feasible. The same corrections are applied for both tyres. The correction is made to the overall A-weighted sound pressure level, with the same correction applied to all frequency bands. Temperature coefficients for tyres P1 and H1 as well as the correction procedure are specified in ISO/TS 13471-1 [10].

3.1.2.2 Quality Assurance

The equipment that is used meets the requirements of type 1 according to IEC 61672-1 (microphones) and class 1 according to IEC 60942 (calibrators). Microphones are checked within M+P twice a year. Periodically, the microphones and calibrators are calibrated by an accredited institute. Annually a test procedure is performed to determine the differences between the various CPX-trailers in use by M+P.

A calibration report is available for the CPX-trailer used. The M+P-trailers participated in the Dutch Round Robin Test organized by CROW [17].

3.2 Measurement Locations

SPB measurements have been taken at 24 locations on the Irish National Road network. Some difficulties were encountered during the measurement campaign in identifying suitable measurement locations. Measurement locations were selected taking into account health and safety requirements as well as ensuring compliance with the SPB requirements discussed in Section 3.1.1.

Specific difficulties that arose were as follows,

- Only official laybys and parking areas were allowed as safe working locations;
- There could be no physical barrier between the measurement location and the road surface, e.g. crash barriers;
- Traffic volumes less than 40,000 AADT were required to ensure a sufficient gap between vehicle pass-bys;
- When traffic volumes were low it was difficult to measure enough HGV pass-bys;
- Difficulties arose in identifying the specific surface type and age of pavements on the network. Assistance was provided by the MMARC's and TII, however, the best approach was to first identify safe measurement locations and then to determine surface type and age at that location. It is anticipated this difficulty may be eliminated in future measurement campaigns if road surface types are now available from the noise mapping exercise.

Surface age definitions depend on the surface type and are as follows,

- SMA 10 and SMA 14 (given the average life span of 10 years)
  - 0-3 years: new condition
  - 3-8 years: medium age
  - ≥9 years: old age
- HRA (given the average life span of 20 years)
  - 0-5 years: new condition
  - 5-15 years: medium age
  - ≥16 years: old age

Table 3.1 below lists all survey locations, including the pavement type and GPS co-ordinates. Appendix C presents further information on the number of pass-bys measured at each location for each vehicle category.

Table 3.1 - Overview of SPB-Locations

Measurement Number	Measurement Date	Surface Type	Surface Age	Route	Latitude	Longitude	Traffic Travel Direction
01	01/03/2022	HRA	Medium	M2	53.454224	-6.354914	N
02	15/03/2022	HRA	Medium	M2	53.445134	-6.35572	S
03	22/03/2022	HRA	Medium	Navan South	53.626984	-6.673005	S
04	25/03/2022	HRA	Medium	N51	53.645294	-6.725274	W
05	25/03/2022	HRA	Medium	N3	53.747327	-6.977669	S
06	28/03/2022	HRA	Medium	N51	53.650062	-6.71102	E
07	01/04/2022	SMA14	Old	M9	53.037162	-6.799388	N
08	08/04/2022	SMA14	Old	M8	52.7663469	-7.5495051	S
09	08/04/2022	SMA14	Old	M8	52.697096	-7.653042	N
10	08/04/2022	SMA14	Old	M8	52.65823	-7.734589	S
11	15/04/2022	SMA14	Old	M8	52.8057365	-7.5009387	S
17	06/07/2022	SMA14	New	N4	54.1295221	-8.4504061	N
18	12/07/2022	SMA14	New	N4	54.1620798	-8.4810041	N
19	20/07/2022	SMA14	New	N4	54.1351449	-8.4554929	S
20	21/07/2022	SMA14	New	N4	54.0931113	-8.3860354	S
21	06/10/2022	SMA10	Medium	M11	52.8598396	-6.1051374	N
22	29/11/2022	SMA 10	Medium	M11	52.5968033	-6.400501	S
23	18/10/2022	SMA14	New	M7	52.641056	-8.5789077	W
24	18/10/2022	SMA14	New	M7	52.6524176	-8.5568203	E
25	23/11/2022	SMA10	Medium	M11S54	52.8595000	-6.1046111	S
26	22/11/2022	SMA10	Medium	M11S50	52.8888964	-6.0993074	S
27	23/11/2022	HRA	Old	M11S57	52.8334558	-6.1246704	S
28	25/11/2022	SMA10	New	M11N90.5	52.61171667	-6.37990278	N
29	03/10/2022	SMA10	New	M11N92	52.6016382	-6.3934696	N

Please note that locations 12 to 16 are omitted from the report. Although these locations were initially included in the measurement plan, it was later realized during the process that there were no safely viable survey locations on those specific road stretches. To address this challenge, CPX measurements were conducted at alternative locations. Some of these alternative locations overlapped with those where SPB measurements were taken, while others were on roads where suitable survey locations were lacking. All CPX measurements were carried out between June 21, 2022, and June 23, 2022.

Table 3.2 - Overview of Locations where CPX-Measurements were Performed

Measurement Number	Surface Type	Surface Age	Route	CPX	Traffic travel direction
01	HRA	Medium	N2	km 5.5 - km 10	N
02	HRA	Medium	N3	km 10 - km 5.5	S
03	HRA	Medium	Navan South	M3 exit 8 - round about R147	S
04	HRA	Medium	N51	roundabout townspark/St Patricks park - roundabout with M3 exit 9	W
05	HRA	Medium	N3	km 61 - km 66	S
06	HRA	Medium	N51	roundabout townspark/St Patricks park - roundabout with M3 exit 9	E
07	SMA14	Old (Laid 2009)	M9	km 18.5 - km 16	N
08	SMA14	Old (Laid 2009)	M8	km 1 8 - km 22	S
09	SMA14	Old (Laid 2009)	M8	km 18 - km 22	N
10	SMA14	Old (Laid 2009)	M8	km 29-33	S
11	SMA14	Old (Laid 2009)	M8	km 37 - km 41	S
13	SMA10	New	M7	km 12 - 19.5	both
14	SMA10	New	M50	km 37.5 - km 45.5	both
15[4]	HRA	New	M4	km 66.7 - km 72.4	both
16	HRA	Old	M7	km 179.5 - km 187	both
17	SMA14	New	N4	km 175.6 - km 190	N
18	SMA14	New	N4	km 175.6 - km 190	N

[4] Measurement results on location 15 (M4) showed inhomogeneous noise levels, with a range of several dB indicating different pavement types within the section. As details were unavailable, the location was excluded from the analysis.

Measurement Number	Surface Type	Surface Age	Route	CPX	Traffic travel direction
19	SMA14	New	N4	km 190 - km 175.6	S
20	SMA14	New	N4	km 190 - km 175.6	S

3.3 Measurement Results

3.3.1 SPB-Method

Figure 3.4 presents the results of the SPB-measurements. Depicted are the weighted average sound levels for the various road surfaces as function of the velocity. The weighted averaging procedure that was followed is described in the Dutch C_{wegdek} method [4] and has been translated to English for the UNECE-GRBP road surface labelling proposal [16], see Appendix E. The weighting is applied based on the number of vehicles during a SPB-measurement. Therefore, the results for a measurement with 150 pass-bys for a given vehicle category will have more influence on the average value than a measurement with 100 pass-bys for the same vehicle category. The number of vehicles for each measurement and vehicle category is given in Appendix C.

The results are only depicted for velocities where the confidence bounds around the average value are sufficiently narrow, as specified in the weighted averaging procedure. For medium heavy vehicles (category 2), the number of vehicles measured is too low to provide sufficiently accurate results. Road surface corrections for these vehicles will be based on SPB measurement results for heavy vehicles (category 3): the increase or decrease in category 2 noise levels for each surface relative to the reference pavement is assumed to be equal to the relative differences found for category 3. This has also been the approach for many of the existing CNOSSOS-EU:2020 corrections.

The results indicate that the measured sound levels at HRA medium are the highest over the whole speed range for passenger cars and heavy-duty vehicles. The lowest sound levels are measured at SMA 14 medium/old for heavy duty vehicles. For passenger cars, the lowest values are measured at SMA 10 new or SMA 14 medium/old. Figure 3.5 show the resulting sound spectra for all surface types.

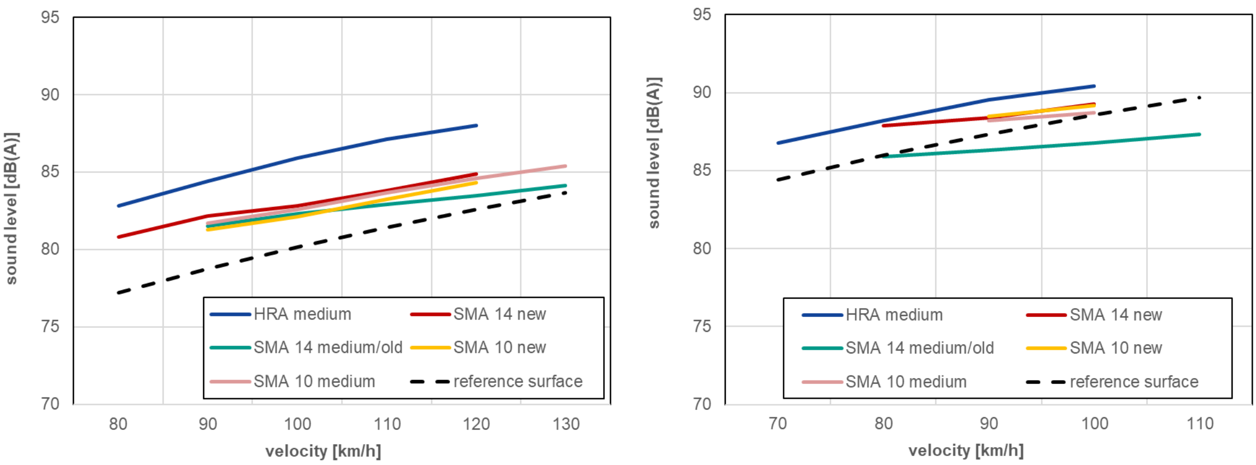

Figure 3.4 - Average SPB-results for the various road surface types as function of the vehicle speed. Left: for passenger cars. Right: heavy duty vehicles.

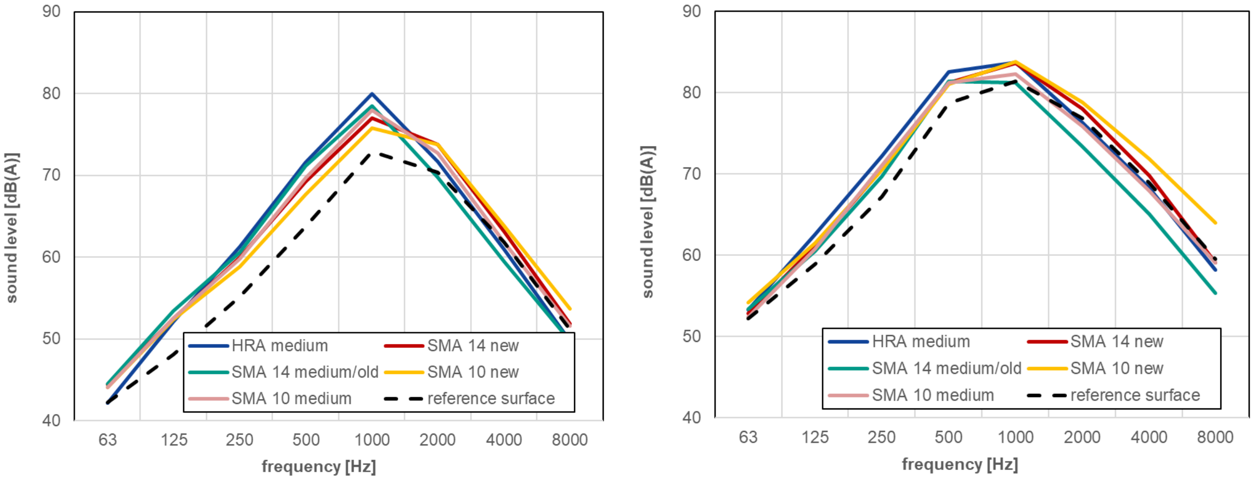

Figure 3.5 - Average sound spectrum for each road surface type at 70 km/h. Left: passenger cars. Right: heavy duty vehicles.

3.3.2 CPX-Method

CPX-measurements were performed in week 25, 2022 at six sections with HRA medium, four sections with SMA 14 new, five sections of SMA 14 medium/old and two sections of SMA 10 new. The average sound pressure levels per surface type are presented in Figure 3.6. The error bars indicate the value of the standard deviation around the average value.

The results indicate that the measured CPXP-levels for HRA medium are the highest. The lowest CPXP-levels are measured for SMA 14 new. SMA 14 medium/old yields CPXP-levels in between HRA medium and SMA 14 new. SMA 10 new indicates 0,5 dB higher results, but given the standard deviations the difference is not statistically significant.

Figure 3.7 shows the corresponding sound spectra. HRA medium and SMA14 medium have a higher sound level for the frequency range up to 1000 Hz. This corresponds to a higher surface texture level.

For SMA 10 new, the CPX measurements show unexpected results compared to SMA 14 new. Due to the larger stone size, higher noise levels for SMA 14 new would be expected than for SMA 10 new, certainly at lower frequencies.

The spectra in Figure 3.7 are nearly identical for both surface types up to 1000 Hz, and SMA 10 new levels are slightly higher than SMA 14 new levels at higher frequencies. Based on these CPX measurement results, it is questionable whether the road surfaces on CPX measurement locations 13 (M7) and 14 (M50) are actually different from SMA 14 new. This conclusion is presented for information purposes only. There is no consequence for the final road surface corrections which are determined from the SPB measurements only and since SPB measurements could not be done on M7 and M50 sections in question due to high traffic volumes.

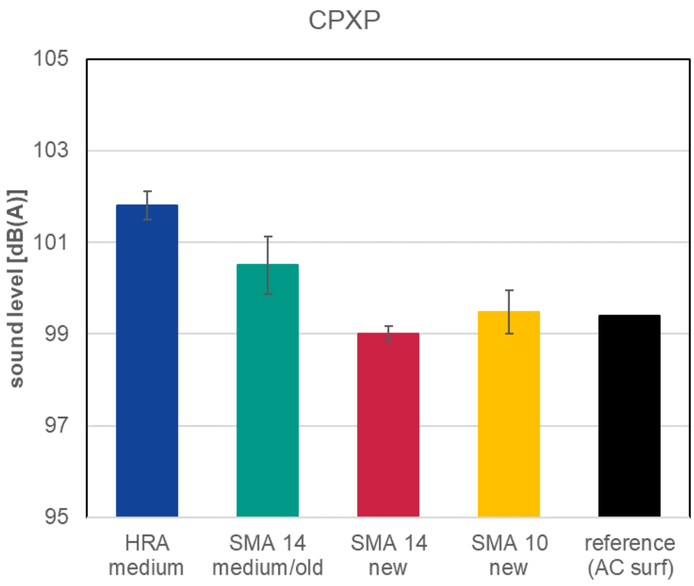

Figure 3.6 - Average CPXP-values at 80 km/h for the different road surface types. As a reference also depicted is the CPXP-value for the reference surface.

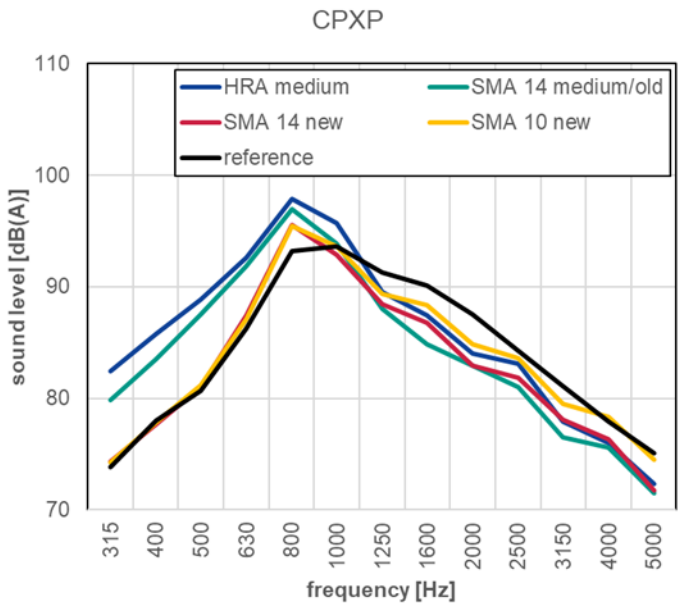

Figure 3.7 - Average CPXP-sound spectra for the different road surface types

Due to time and weather constraints during the measurement campaign, results for tyre H1 could not be measured on several of the measurement sections.

The CPX_H results for tyre H1 have therefore not been utilized in this analysis. Limitations to the results and conclusions will be indicated below where appropriate.

3.4 Interpretation of Results

In the paragraphs below, the measurement results are further elaborated for each of the pavement types.

The analysis and discussion differs for each road surface, depending on the availability of SPB and/or CPX measurement results. In addition, historical CPX measurements obtained by TII during previous research in 2019 are also used to aid the interpretation of HRA results, see Appendix D. The road surface corrections will be based on SPB measurement results, as explained in paragraphs 1.2 and 2.3.3. The CPX measurement results were used to check the pavement acoustic homogeneity at and around the SPB measurement position and they are also used below to aid conclusions with regards to the influence of pavement age (new, medium or old) on the acoustic performance.

3.4.1 Hot Rolled Asphalt

SPB-measurements on six sections of road with HRA medium age have been performed to determine the correction surface for medium age HRA. Note that it was not possible to identify locations suitable for SPB-measurements for newly laid HRA pavements. However, CPX-measurements have been performed in 2022 as well as in an earlier measurement campaign by M+P in 2019, at nine locations in total: three locations with new HRA and six with medium aged HRA. In this paragraph, the 2019 results [15] are combined with the 2022 measurement shown in paragraph 3.3.2, in order to determine if new and medium age HRA show significant differences in rolling noise.

The average CPX-results for tyre P1 are depicted in Figure 3.6, both the overall level and the frequency spectrum are presented. All measurements are performed at 80 km/h. The green line represents new HRA and red represents medium aged HRA. The error bars indicate the standard deviation over the results for the different locations. First considering the overall level, the two pavement ages are equivalent in their sound level within the measurement uncertainty. Slightly larger differences in individual third-octave band filters up to 2.5 dB have been observed. These differences do not lead to a significant difference in overall level between HRA new and HRA medium age.

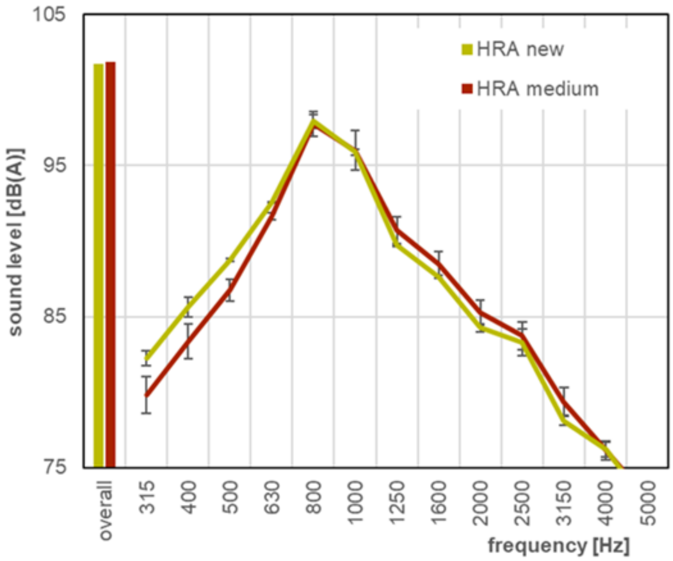

Figure 3.8 - CPX-levels for new and medium aged Hot Rolled Asphalt for tyre P1 at 80 km/h, as a function of frequency in third-octave bands

All correction factors produced as part of this research will be based on SPB-measurements. SPB-measurements are an average over many vehicles and therefore considered to be more accurate and representative of the average current vehicle population. Also, the roadside measurement position is more representative of the actual road surface effect at greater distances. CPX measurements are limited to very specific tyres and limited in frequency range. Additionally, the adequacy of CPX measurements to represent heavy goods vehicles is uncertain.

While there is presently no established standard or guidance on determining CNOSSOS-EU correction factors, all existing correction factors provided with CNOSSOS-EU are derived from SPB measurements, which serve as the regulatory standard method in the Netherlands.

Therefore, a method is required to determine if differences noted between pavements of various ages using the CPX method can be translated to the SPB method. M+P previously developed a relationship between CPX and SPB for this purpose [18], based on locations where both SPB and CPX measurements have been conducted in the past. The slope of this relationship equals 1, which means that differences in sound levels between SPB and CPX results are equal. Hence, a difference of 2 dB in CPX sound level translates into a 2 dB difference in SPB-level.

Note that the CPX sound levels are on the outer range of the SPB/CPX relationship: the correlation identified by M+P primarily relies on measurement data from pavements with noise levels within or below the range of the reference surface. However, the Irish pavements under discussion here exceed the reference levels to some extent. However, this is not expected to significantly change the value of the slope and therefore it is not expected that SPB measurements will show a significant difference between HRA new and medium.

In conclusion, the evidence suggests that there is an insignificant difference in SPB-levels between HRA new and medium age.

CPX_H results for tyre H1 are not available. However, this tyre is less sensitive to surface texture variations than tyre P1, due to the coarser tread profile. Therefore, noise levels differences between HRA new and medium age, which will be caused by differences in texture, will be smaller for tyre H1 than for tyre P1. Not having measurement results for tyre H1 does therefore not impact this conclusion. In line with this, truck tyres are also generally equally or less sensitive to texture variations, certainly for the many trucks that are equipped with traction tyres. Therefore, the conclusion drawn for tyre H1, indicating that noise levels do not significantly differ between HRA new and medium, can also be confidently extended to trucks.

3.4.2 SMA 10

Figure 3.9 shows the SPB-results at the sections with SMA 10 for light motor vehicles at 110 km/h and heavy-duty vehicles at 90 km/h. Each bar indicates the noise level at this reference speed for an individual measurement location. The results are differentiated between new and medium age.

As explained in Section 3.3.2, CPX results measured on two SMA 10 new locations seem implausible. As these CPX measurements were performed on locations other than the SPB measurement locations, there is no consequence for the final road surface corrections. The CPX results for SMA 10 new are therefore not discussed further here.

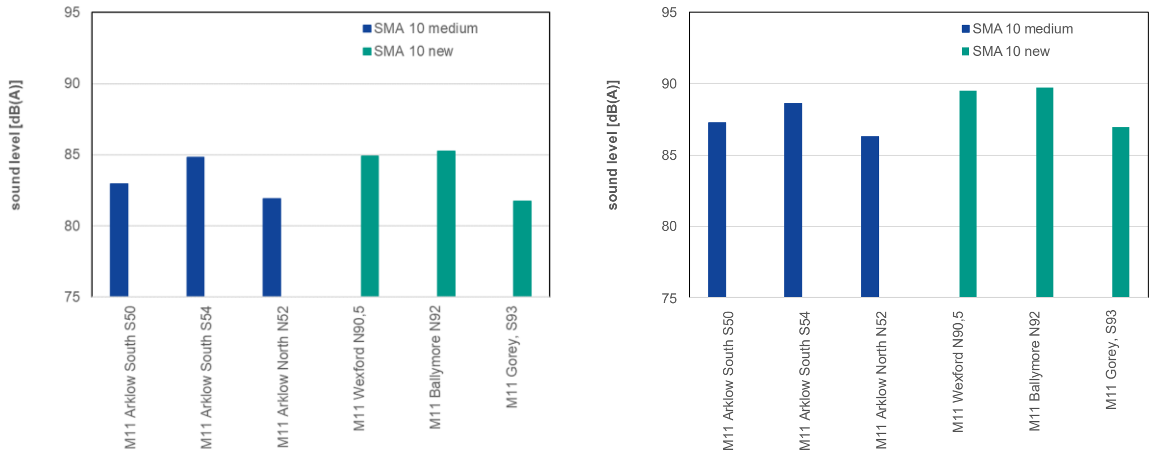

Figure 3.9 - Measured SPB-levels at SMA 10. Left: sound levels for passenger cars at 110 km//h. Right: sound levels for heavy duty vehicles at 85 km/h.

In summary, a distinct contrast in the overall sound levels between SMA 10 new and SMA 10 medium age is not evident. Supporting this conclusion, Figure 3.10 illustrates the sound level spectra for passenger cars and heavy duty vehicles at the SMA 10 sections. Note that medium heavy vehicles are not considered separately, as explained in Section 3.3.1. Differences are observed between SMA 10 medium and SMA 10 new in the higher frequency octave bands (⩾ 2 kHz), where the SMA 10 new shows somewhat higher levels than SMA 10 medium. However, the differences are within the measurement uncertainty and are smaller than the differences between the results of the various road sections. The latter is indicated by the overlapping error bars, which represent the standard deviation over the measured levels of the different road sections.

The initial SMA 10 analysis incorporated SPB results from the M11 Arklow South S57 (location 27). However, the analysis revealed significantly higher noise levels at this location compared to other SMA10 locations (refer to Figure 3.10). Subsequent inquiries with the local MMaRC road contractor indicated that the road surface on this section is not SMA10 but likely an old HRA. Consequently, the data from this location have been excluded from further analysis.

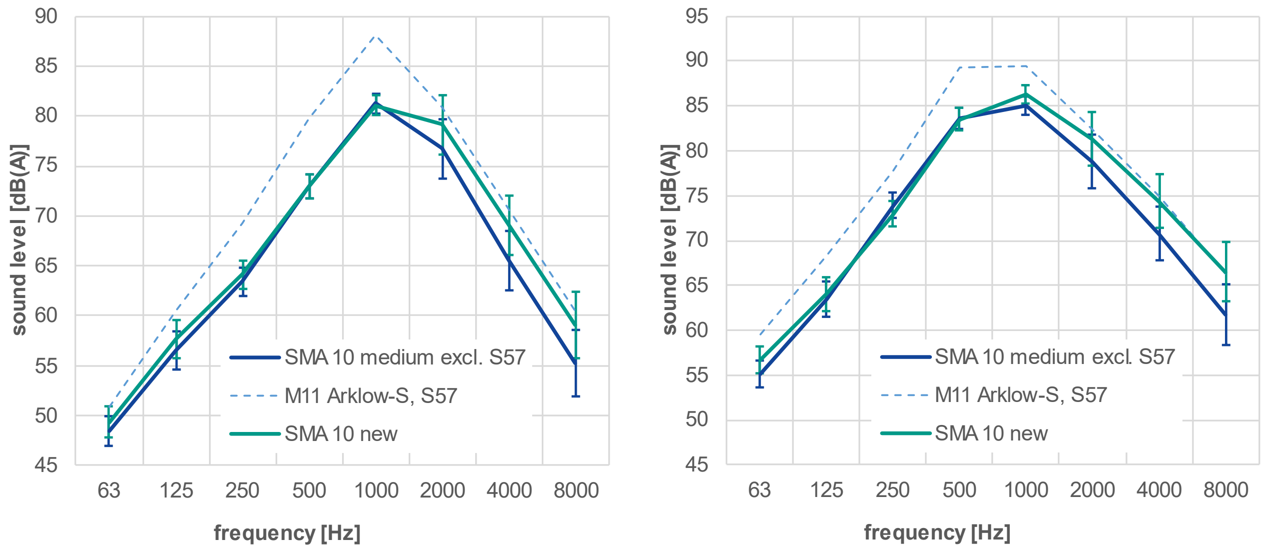

Figure 3.10 - Left: sound spectra for passenger cars. Right: sound spectra for heavy duty vehicles

Based on these observations the evidence concludes that it is appropriate to use one set of correction factors for SMA 10 which is independent of the age of the surface. It should be noted that measurement data for SMA 10 is only available for the M11 motorway. It is possible that several of these sections may have been paved by a single road contractor at a single time. It is recommended to reevaluate this conclusion in the future if more data from different SMA 10 sections of different ages become available.

3.4.3 SMA 14

SPB and CPX measurements were conducted on new as well as medium/old surfaces for SMA14. Figure 3.11 presents the outcomes for both measurement methods, averaged across all locations where both SPB and CPX measurements were taken. In the SPB measurements at 110 km/h, the graph illustrates that the sound level on SMA 14 new is higher than on SMA 14 medium/old, consistent with the findings for SMA 10 discussed in the preceding section. In contrast, the CPX results show the opposite trend regarding the overall total dB-levels (the bars on the left side of the graph), indicating that SMA 14 medium/old produces higher CPX levels than SMA 14 new.

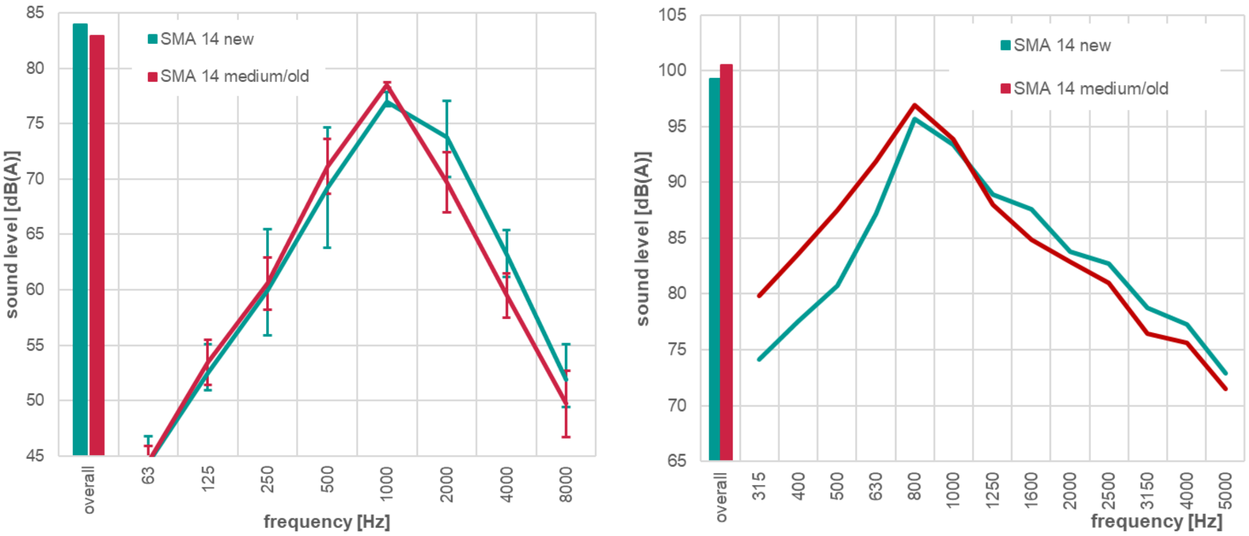

Figure 3.11 - Measurement results for SMA 14. Left: results for SPB-measurements for passenger cars/ Right: CPXP-results

The sound spectra, also depicted in Figure 3.11, explain these different results. Comparing the differences in the sound spectra between SMA 14 new and medium age for SPB and CPX, illustrates the same trends. For frequencies higher than 1000 Hz, a decrease of the sound level over time is observed. This is evidence of the surface becoming more open/porous over time. A higher porosity manifests itself as a decrease in the sound level for higher frequencies. However, between 250 and 1000 Hz an increase of the sound level over time is observed. This is evidence of the surface texture becomes higher. Both phenomena (higher porosity and coarser surface texture) are caused by loss of (fine) material in the surface.

It is also clear that differences in the low frequency range are more prominent in the CPX-results due to the specific characteristics of the P1-tyre. In the SPB-results, which are based on a wide range of tyres as carried by normal traffic, no significant differences over time are observed for frequencies below 250 Hz.

Figure 3.12 illustrates the results for the SPB-measurements for passenger cars and heavy duty vehicles. The error bars indicate the value for the standard deviation over the results of the different road sections.

The results for the heavy-duty vehicles show a similar behaviour over time for the high frequencies. For the lower frequencies, there is no difference between SMA 14 new and SMA 14 medium/old as truck tyres are much less sensitive to variation in surface texture.

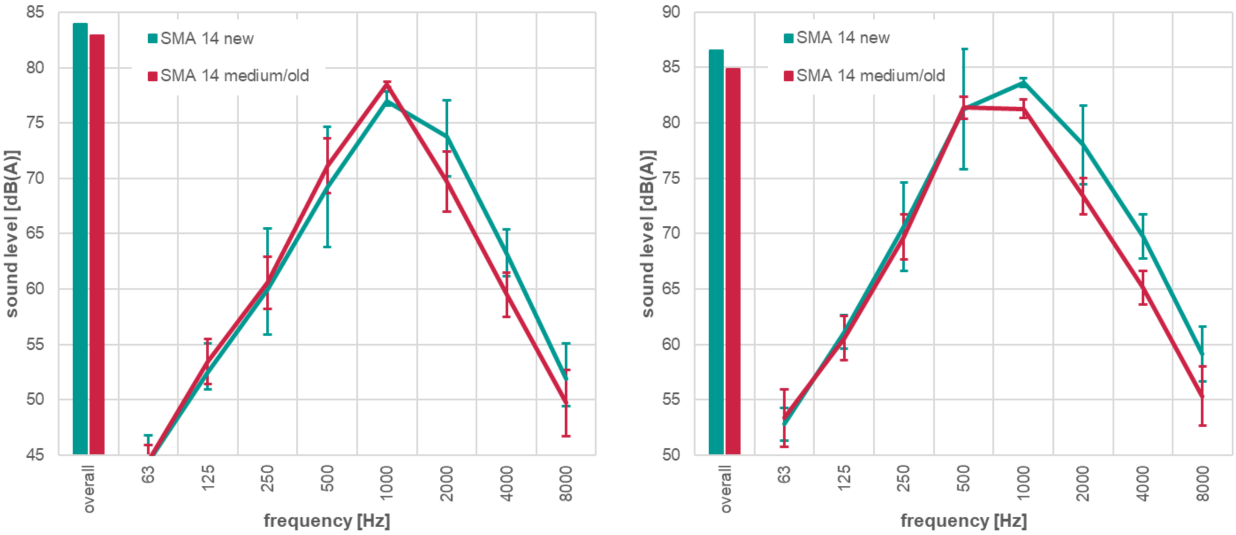

Figure 3.12 - SPB-result on SMA 14 for passenger cars (left) and for heavy duty vehicles (right)

Reviewing the results in Figure 3.12 for frequencies ⩾1000 Hz, the differences between SMA 14 new and SMA 14 medium/old are significant as the error bars hardly overlap. That holds especially for heavy duty vehicles.

Hence, relying solely on SPB results, two sets of correction factors for SMA 14 are considered valid—one for SMA 14 new and another for SMA 14 medium. Conversely, several factors support the idea that a single set of correction factors is more appropriate. Firstly, when considering noise at a greater distance from the road, lower-frequency noise becomes more relevant than higher-frequency noise. In this lower-frequency range, the distinctions between SMA14 new and medium age are negligible. Therefore, it can be anticipated that the sound level difference between SMA 14 new and medium is not significant at a greater distance from the road. Secondly, the future impact of further aging on the road surface remains uncertain. As time progresses, the surface texture is expected to become coarser, potentially resulting in an increase in sound level. Finally, practical implementation of different correction factors based on pavement age necessitates detailed information about the road surface's age, which may not be readily available to the NMB.

4. Road Surface Correction Factors

4.1 Reference Surface

As explained in Section 2.3.2, the road surface correction factors in CNOSSOS-EU:2020 are defined with respect to a reference surface, which 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.

This definition of the reference road surface does not point to a single well-defined pavement type. Road surface correction values made available in the CNOSSOS-EU:2020 appendices [2], see Section 2.3.3, are taken directly from the Dutch C_{wegdek} system and are relative to the Dutch reference road surface, which is considered to comply with the definition above. By taking over the Dutch correction factors, the CNOSSOS-EU:2020 and the Dutch reference surface are considered to be equal by definition.

Alternative options for an Irish or TII-specific reference road surface have been considered [11], for instance to use the SMA10 or SMA14 measurement results as a reference surface. As the results for these surfaces do differ from the CNOSSOS-EU:2020 / Dutch reference surface, switching to a different surface would require a correction of the CNOSSOS-EU:2020 noise emission coefficients (Section 2.3.1), or additional measurements to measure the current average traffic fleet emissions on the new reference surface. For the purpose of this research project the CNOSSOS-EU:2020 / Dutch reference road surface was adopted. If in the future TII performed a new set of measurements to recalibrate the noise emission coefficients, they may also reconsider the definition of the reference surface.

Reference noise levels for the Dutch reference road surface are defined as $L_{ref,i,m} = a_{i,m} + b_m \cdot \log_{10}(v_m/v_{ref,m})$, where i is the 1/1-octave band index and m is the vehicle category index. The $a_{i,m}$ values are the noise levels at the reference speed $v_{ref,m}$, which are found by adding the spectrum correction value $\Delta_{ai,m}$ to the overall offset $a_{0,m}$. The b_m values are the speed coefficients, i.e. the increase of noise levels with vehicle speed. Values are given in Table 4.1 and Table 4.2 below.

Table 4.1 - Total Noise Level Values for the Reference Surface

	$a_{0,m}$	b_m	$v_{ref,m}$
m = 1 (light motor vehicles)	77.2 dB(A)	30.6	80 km/h
m = 2 / 3 (medium / heavy vehicles)	84.4 dB(A)	27.0	70 km/h

Table 4.2 - Spectrum Correction Values for the Reference Surface

	i = 1 63 Hz	i = 2 125 Hz	i = 3 250 Hz	i = 4 500 Hz	i = 5 1 kHz	i = 6 2 kHz	i = 7 4 kHz	i = 8 8 kHz
m = 1 (light motor vehicles)	-33.2	-27.3	-20.3	-11.7	-2.5	-5.1	-13.6	-24.3
m = 2 / 3 (medium / heavy vehicles)	-32.2	-25.5	-17.2	-5.7	-3.0	-7.6	-15.5	-24.9

4.2 Development of the Correction Factors

To establish the road surface correction factors for each pavement type, different data analysis steps are followed:

1. For each pavement type, the SPB-measurement results at different locations are averaged following a weighted averaging procedure based on the number of pass-bys at each location, as described in Section 3.3.1. The exact calculation procedure is defined in the Dutch C_{wegdek} schema, an English description of which is given in Annex II of the UNECE road labelling proposal [16], copied in Appendix E of this report. Also, this procedure defines the vehicle speed range within which the end results are considered to be sufficiently accurate. This step results in average SPB levels for each pavement type in 1/1-octave frequency bands, in terms of the $a_{SPB,i,m}$ and $b_{SPB,m}$ coefficients in $L_{SPB,i,m} = a_{SPB,i,m} + b_{SPB,m} \cdot \log_{10}(v_m/70)$.
2. For each pavement type, the difference with respect to the reference surface is calculated, per frequency band. Values for the reference surface are given in Section 4.1. This step results in preliminary road surface correction factors $\alpha_{i,m}$ and β_m.

The factors $\alpha_{i,m}$ and β_m are now calculated as corrections to the overall vehicle noise emissions, i.e. the total of rolling and propulsion noise. The road surface corrections are, however, applied to rolling and propulsion noise contributions separately and in a different manner, see Section 2.3.3. If the preliminary correction factors $\alpha_{i,m}$ and β_m would be directly applied, then any rise in noise emission for road surfaces louder than the reference surface would be underestimated as the additional noise is only applied to the rolling noise and not the propulsion noise. In situations where propulsion noise is significant (e.g. heavy vehicles, low vehicle speeds and/or low frequency bands), this would lead to an inaccurate calculated noise emission. Additional calculations are therefore applied as follows:

3. Using the preliminary $\alpha_{i,m}$ and β_m values, the rolling and propulsion noise emissions are calculated using equations (1) to (6) and summed to a total noise emission, for each frequency band and vehicle category. The total noise emission thus calculated for the particular road surface is compared to the total noise emission for the reference road surface. The difference between the two is then used to correct the $\alpha_{i,m}$ factors for the road surface type. The result is adapted $\alpha_{i,m}$ factors for that particular road surface, for each frequency band and vehicle category.

This procedure leads to an exact correction for a single vehicle speed. The vehicle speed at which step 3 is performed is therefore chosen to be typical for that particular road surface type. In the case of the HRA, SMA10 and SMA14 pavements in this report, typical speeds are chosen as 110 km/h for light vehicles and 85 km/h for medium and heavy vehicles. To obtain results for other vehicle speeds as accurately as possible, a last calculation step is performed to correct the speed coefficient β_m:

4. For each speed decade[5] in the applicable speed range for the particular road surface type, the noise emission is calculated using the adapted $\alpha_{i,m}$ (from step 3) and β_m, and compared to the noise emission for the reference surface. The difference is then compared to what it should be, which is the difference between the measured L_{SPB} level for that road surface and the SPB level of the reference surface. A numeric optimisation routine is then followed to repeat this calculation with slightly modified values of the speed β_m, until the optimal β_m is found at which the remaining error over the whole speed range is minimal. The result is adapted βm factors for that particular road surface type, for each vehicle category.

4.3 The Road Surface Correction Factors

The calculation steps described in Section 4.2 have been followed for the HRA, SMA10 and SMA14 measurement results described in Section 3.3. Table 4.3 below shows the final road surface correction values $\alpha_{i,m}$ and β_m for HRA, SMA10 and SMA14. For SMA14, results based on the average result for all SMA14 sections ('SMA 14') are given, as well as for the subsets of new and medium aged surfaces ('SMA 14 new' and 'SMA 14 medium'). As the SPB results for both subsets differ from the overall average, the resulting coefficients are also different. As it is advised in Section 5 not to distinguish between new and medium aged SMA 14, these values are for information purposes only.

Road surface correction factors are given for light vehicles (Category 1), medium heavy vehicles (Category 2) and heavy vehicles (Category 3). For medium heavy vehicles, no separate SPB measurement results are available as the number of vehicles measured in this category is too low, see also Section 3.3.1. To overcome this it has been assumed that differences found between SPB measurements on different road surfaces will be similar for medium heavy and heavy vehicles.

As the sound power emissions of medium heavy and heavy vehicles are different, as well as the relative contributions of rolling and propulsion noise, the calculation procedure described in Section 4.2 above leads to different road surface corrections for medium heavy and heavy vehicles. Separate corrections are therefore given for these categories in Table 4.3 below.

Table 4.3 - Road Surface Correction Factors $\alpha_{i,m}$ and β_m per Frequency Band *i* and Vehicle Category *m*

light vehicles	$\alpha_{1,1}$	$\alpha_{2,1}$	$\alpha_{3,1}$	$\alpha_{4,1}$	$\alpha_{5,1}$	$\alpha_{6,1}$	$\alpha_{7,1}$	$\alpha_{8,1}$	β_1
HRA	-0.2	5.8	8.6	8.6	7.1	1.4	-0.9	-1.3	-1.2
SMA 10	4.2	6.3	6.5	6.1	4.7	3.4	1.2	1.8	-7.8
SMA 14	3.6	7.4	7.5	8.1	5.9	0.8	-1.5	-1.2	-11.2
SMA 14 new	5.9	6.2	7.0	6.5	4.5	4.0	1.7	0.7	-6.9
SMA 14 medium	0.8	7.5	7.9	8.9	6.4	0.0	-2.4	-1.8	-14.6
medium heavy vehicles	$\alpha_{1,2}$	$\alpha_{2,2}$	$\alpha_{3,2}$	$\alpha_{4,2}$	$\alpha_{5,2}$	$\alpha_{6,2}$	$\alpha_{7,2}$	$\alpha_{8,2}$	β_2
HRA	8.2	8.0	8.9	5.0	3.2	-0.7	-0.8	-1.5	-3.6
SMA 10	2.1	4.8	6.7	2.8	2.1	0.2	1.2	2.8	-12.5

[5] A decade in terms of speed is a group or set of 10, for example 30-40km/h, 40-50km/h etc.

SMA 14	0.0	3.8	5.0	2.6	1.2	-1.2	-1.8	-2.4	-14.6
SMA 14 new	0.0	4.9	5.9	2.3	3.5	3.4	1.7	-0.6	-9.2
SMA 14 medium	0.0	2.0	4.2	3.2	-0.7	-4.3	-4.7	-4.9	-17.2
heavy vehicles	**$\alpha_{1,3}$**	**$\alpha_{2,3}$**	**$\alpha_{3,3}$**	**$\alpha_{4,3}$**	**$\alpha_{5,3}$**	**$\alpha_{6,3}$**	**$\alpha_{7,3}$**	**$\alpha_{8,3}$**	**β_3**
HRA	8.7	8.6	9.0	5.0	2.9	-0.6	-0.8	-1.5	-3.6
SMA 10	2.2	5.2	6.8	2.8	1.9	0.5	1.2	2.9	-12.5
SMA 14	0.0	4.1	5.1	2.6	1.2	-1.0	-1.7	-2.4	-14.6
SMA 14 new	0.0	5.4	6.0	2.2	3.1	2.8	1.6	-0.6	-9.2
SMA 14 medium	0.0	2.1	4.3	3.2	-0.6	-4.0	-4.6	-4.9	-17.2

Figure 4.1 illustrates the effect of these corrections on the calculated road noise emissions, using the HRA, SMA 10 and SMA 14 correction factors given above.

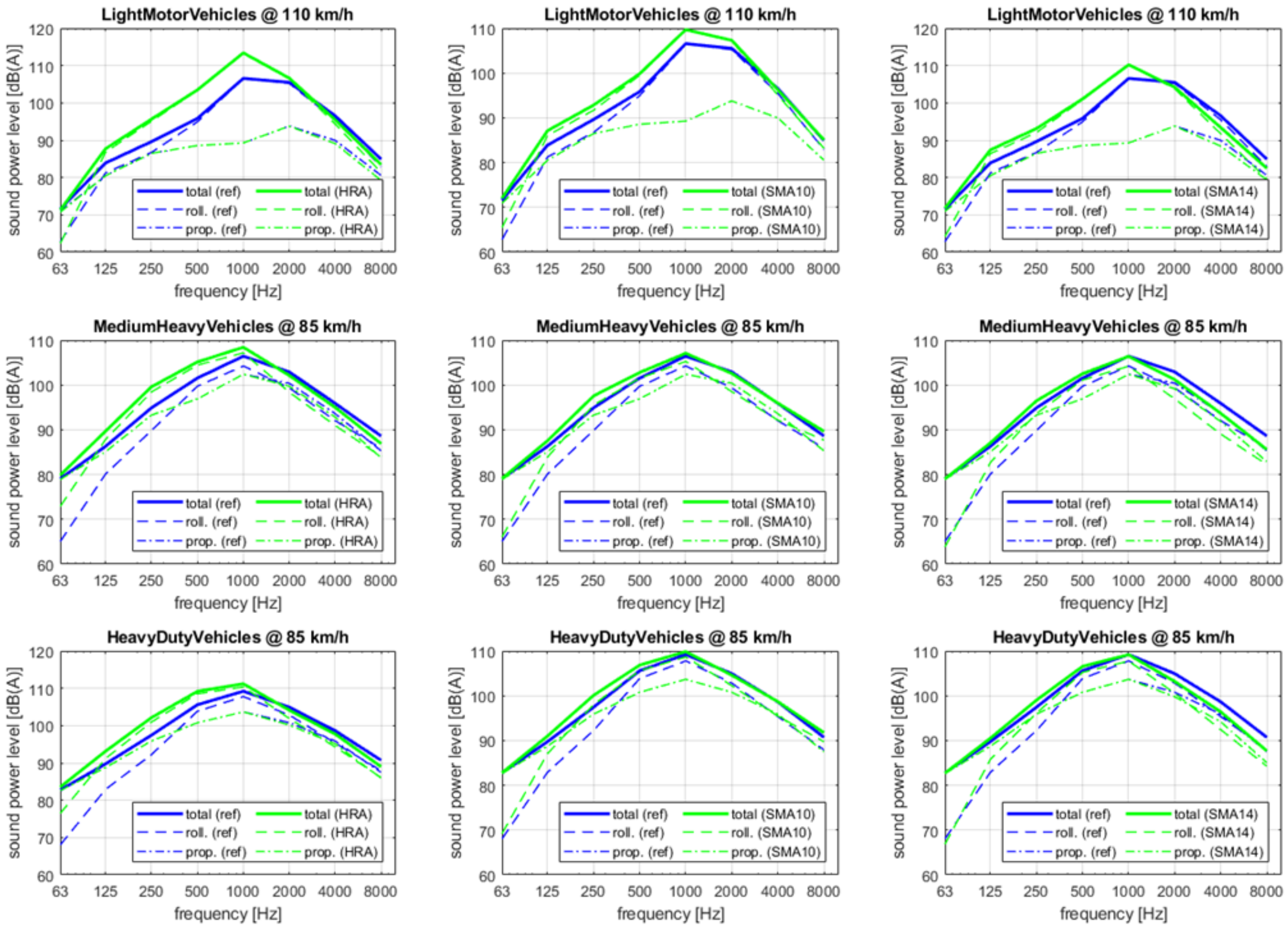

Figure 4.1 - Calculated rolling noise, propulsion noise and total noise emission spectra for each vehicle category at typical application speeds. Green lines show results for HRA (left), SMA10 (middle) and SMA14 (right), blue lines show the results for the reference surface

5. Conclusions and Recommendations

5.1 Conclusions

The CNOSSOS-EU noise assessment model utilized for strategic noise mapping does not currently incorporate road surface correction factors tailored to the surface types commonly employed on Irish roads. This study has undertaken the development of new road surface correction factors specifically for Hot Rolled Asphalt (HRA), Stone Mastic Asphalt 14mm (SMA14), and Stone Mastic Asphalt 10mm (SMA10). These correction factors have been established through a series of Statistical Pass-By (SPB) measurements conducted at various locations across Ireland. Additionally, Close Proximity (CPX) measurements have been conducted, to verify that SPB measurement locations are representative and to aid the analysis of the influence of pavement age.

SPB measurements on the same road surface type across multiple locations have been combined into a weighted average SPB result for that surface type. Road surface correction factors intended for use with CNOSSOS-EU have been derived from these SPB results using a post-processing calculation procedure, as detailed. Consequently, correction factors for the three surface types—HRA, SMA14, and SMA10—have been formulated for each of the three primary vehicle categories: light, medium-heavy, and heavy vehicles. The correction factors are listed in Section 4.3.

Within each surface type, measurements were completed on road surfaces of different age: new, medium and old, as far as suitable SPB locations could be found. The influence of pavement age was not always consistent between SPB and CPX measurement results. However, the importance of this inconsistency has been explained within the report from the different relative importance of lower versus higher frequencies between both measurement methods. For noise mapping, lower frequencies have a greater influence on noise propagation over greater distances and in situations with noise barriers; at these frequencies, differences between age groups are negligible. In addition, if a distinction between age groups were to be made, surface age data would be required for every stretch of pavement, which may be difficult to obtain in practice.

Therefore, it is recommended not to differentiate between different surface age groups and to employ one set of correction factors for each surface type regardless of age. The correction factors listed in Section 4.3 are based on a combination of new and medium-age surfaces, aligning with the guidelines of the CNOSSOS-EU method.

5.2 Recommendations

Identifying suitable locations on TII roads with the correct surface type and age for SPB measurements, while ensuring safety and accessibility, has proven challenging, particularly for SMA10 and new HRA pavements. Additionally, the correction factors for SMA10 are derived from a limited number of locations, all situated on the M11 and potentially constructed by a single contractor. To enhance statistical robustness, it is advisable to establish corrections based on diverse locations and contractors. A recommendation is made for future construction or repaving projects to include further SPB measurements on these locations. In anticipation of the next round of noise mapping around 2026, it is suggested to reevaluate and adjust road surface corrections for SMA10, and potentially other surface types, based on a more extensive dataset.

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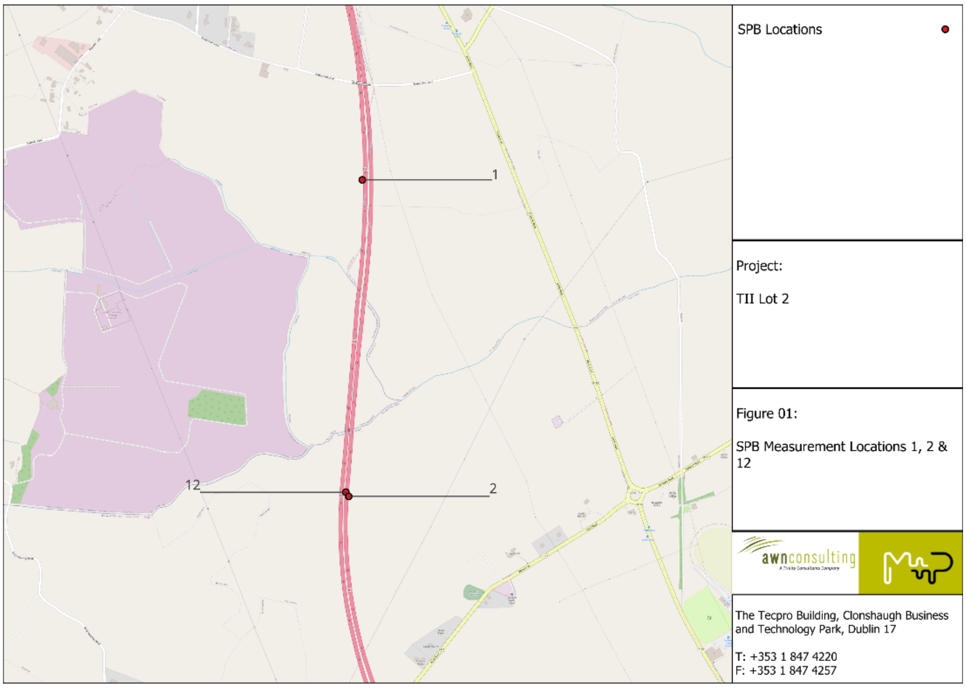
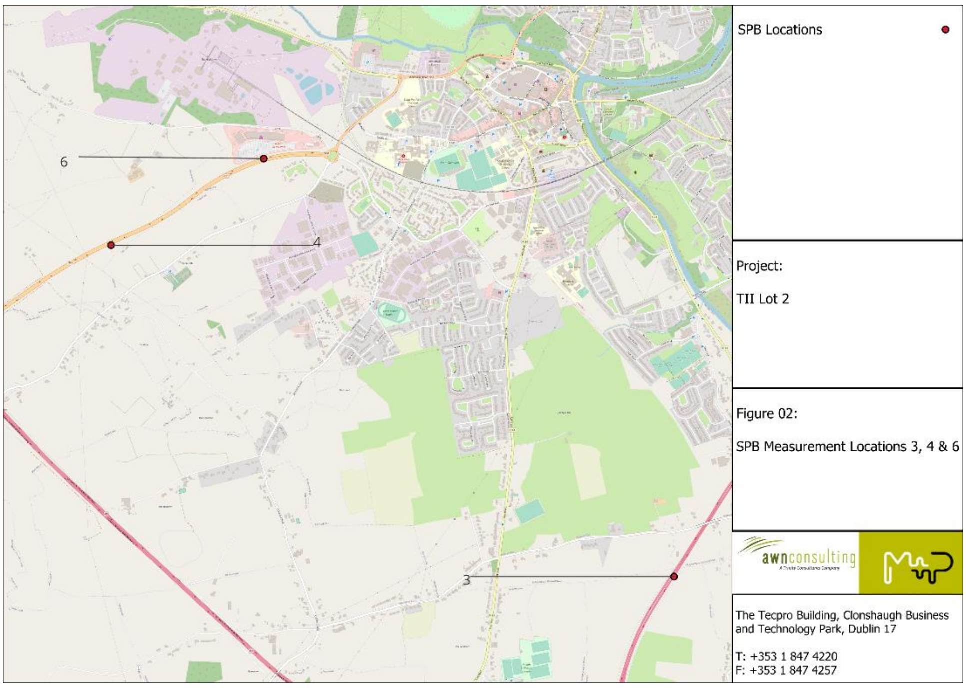
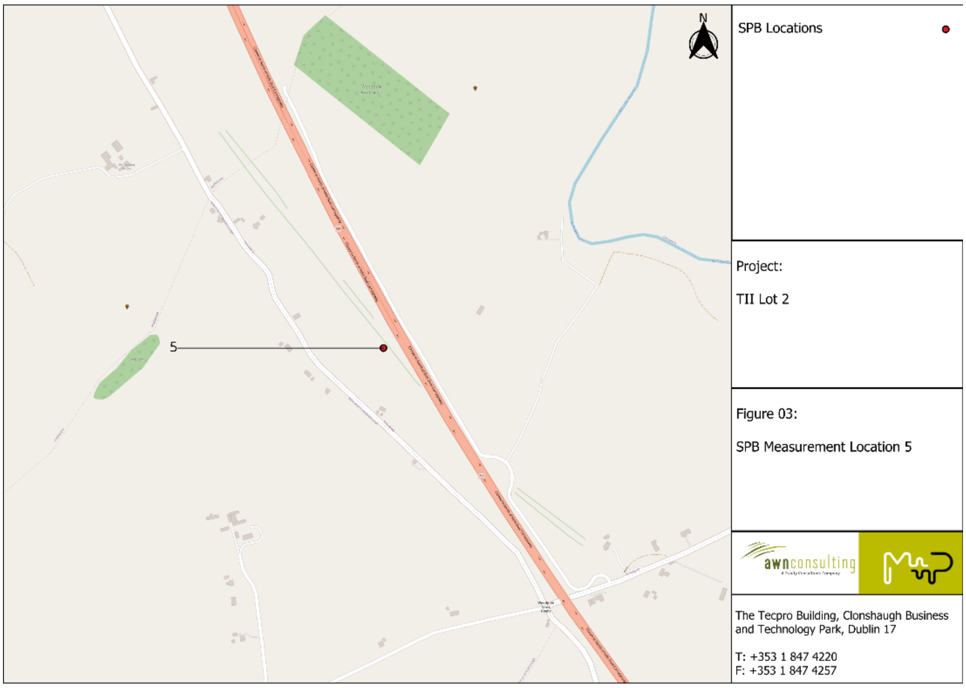
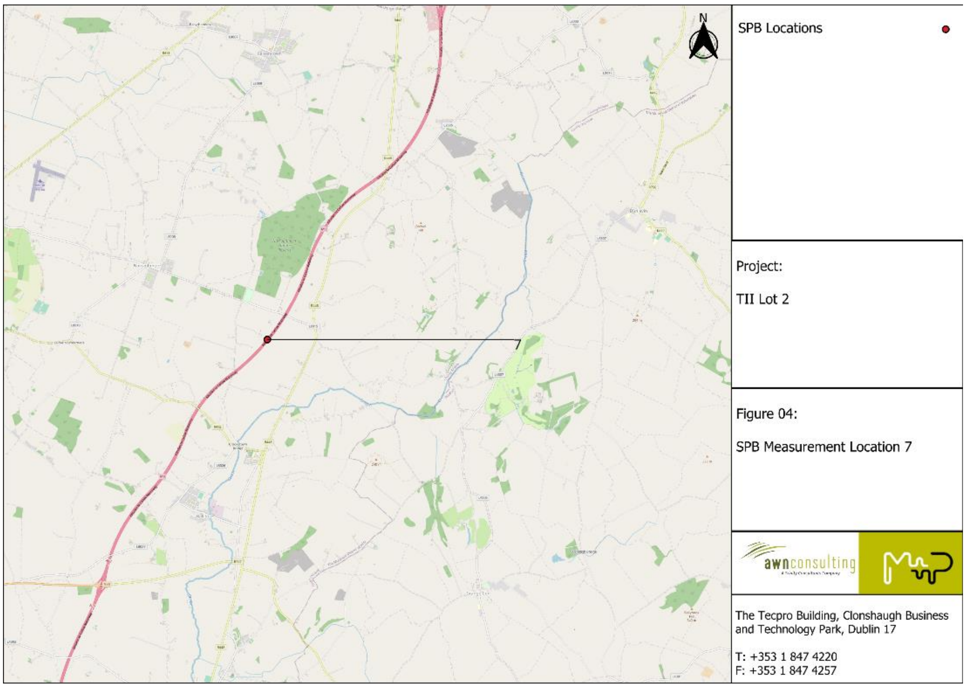
Appendix A - Map of Measurement Locations


1
12
2
SPB Locations
Project:
TII Lot 2
Figure 01:
SPB Measurement Locations 1, 2 & 12
awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257


6
4
3
SPB Locations
Project:
TII Lot 2
Figure 02:
SPB Measurement Locations 3, 4 & 6
awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257


5
N
SPB Locations
Project:
TII Lot 2
Figure 03:
SPB Measurement Location 5
awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257


7
N
SPB Locations
Project:
TII Lot 2
Figure 04:
SPB Measurement Location 7
awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
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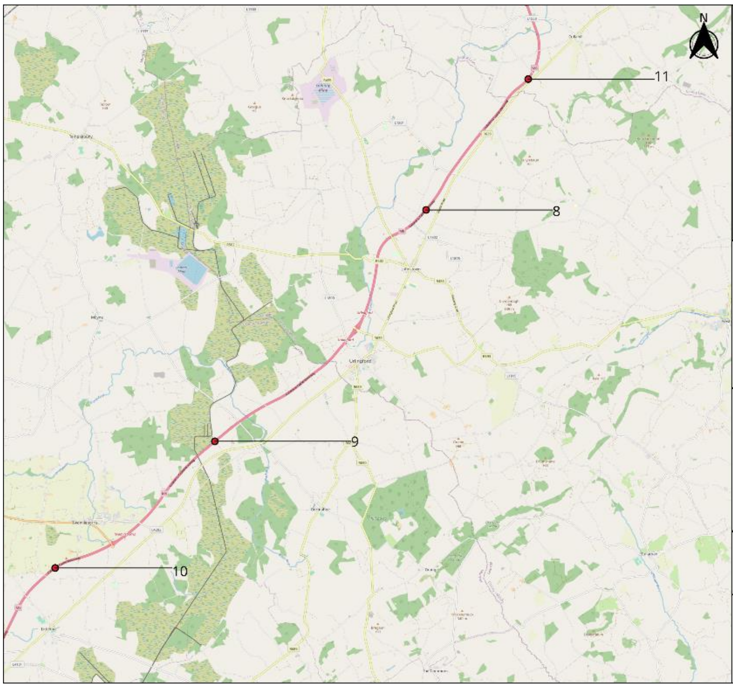
F: +353 1 847 4257



SPB Locations

Project:

TII Lot 2

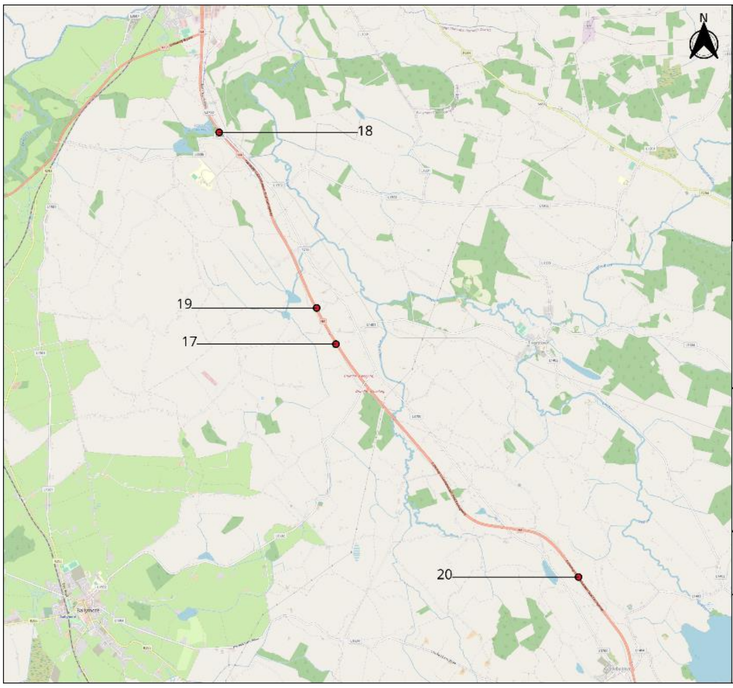
Figure 05:

SPB Measurement Locations 8, 9, 10 & 11

awnconsulting

The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17

T: +353 1 847 4220
F: +353 1 847 4257



SPB Locations

Project:

TII Lot 2

Figure 06:

SPB Measurement Locations 17, 18, 19 & 20

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The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17

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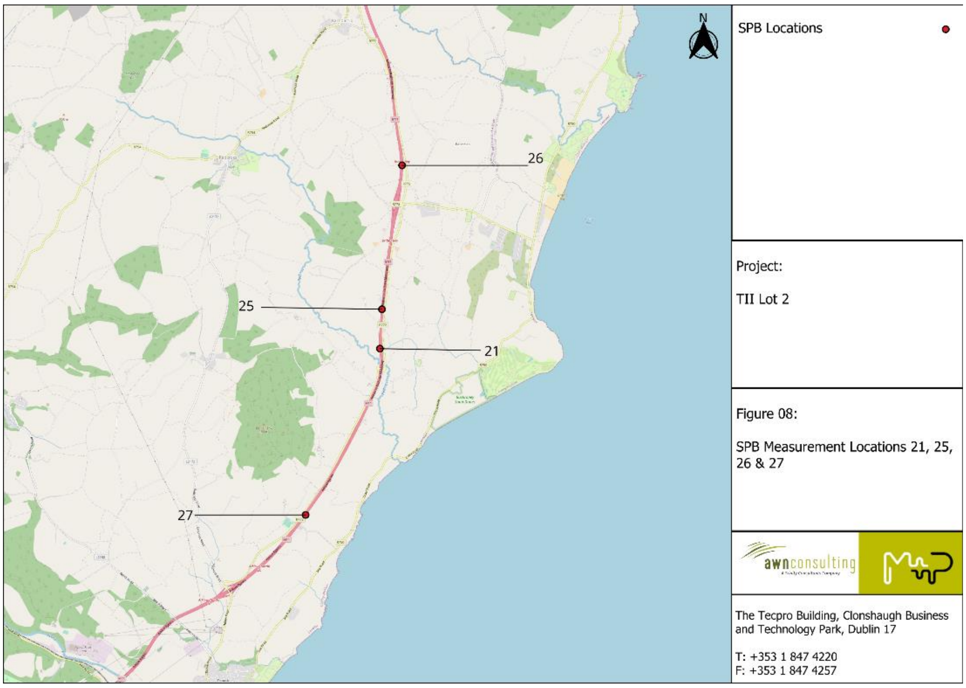
N
SPB Locations
24
23
Project:
TII Lot 2
Figure 07:
SPB Measurement Locations 23 & 24
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257


N
SPB Locations
26
25
21
27
Project:
TII Lot 2
Figure 08:
SPB Measurement Locations 21, 25, 26 & 27
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257


N
28
29
22
SPB Locations
Project:
TII Lot 2
Figure 09:
SPB Measurement Locations 22, 28 & 29
awnconsulting
The Tecpro Building, Clonshaugh Business and Technology Park, Dublin 17
T: +353 1 847 4220
F: +353 1 847 4257

Appendix B - Photographs of Measurements

Measurement Number	Photo
01	
02	

Measurement Number	Photo
03	

Measurement Number	**Photo**
04	
05	

Measurement Number	Photo
06	

Measurement Number	Photo
07	

Measurement Number	**Photo**
08	

Measurement Number	Photo
09	

Measurement Number	Photo
10	

Measurement Number	**Photo**
11	

Measurement Number	**Photo**
17	
18	

Measurement Number	**Photo**
19	

Measurement Number	Photo
20	
21	

Measurement Number	Photo
22	

Measurement Number	**Photo**
23	
24	

Measurement Number	**Photo**
25	

Measurement Number	Photo
26	

Measurement Number	Photo
27	

Measurement Number	Photo
28	

Measurement Number	**Photo**
29	

Appendix C - Details of Measurements

Location	Vehicle Category	Number of Passbys
01	Cars	130
	Medium	11
	Multi Axle Heavy	66
02	Cars	67
	Medium	8
	Multi Axle Heavy	43
03	Cars	130
	Medium	5
	Multi Axle Heavy	25
04	Cars	155
	Medium	21
	Multi Axle Heavy	60
05	Cars	107
	Medium	19
	Multi Axle Heavy	62
06	Cars	138
	Medium	40
	Multi Axle Heavy	35
07	Cars	0
	Medium	0
	Multi Axle Heavy	0
08	Cars	100
	Medium	30
	Multi Axle Heavy	50
09	Cars	130
	Medium	13
	Multi Axle Heavy	74

Location	Vehicle Category	Number of Passbys
10	Cars	125
	Medium	26
	Multi Axle Heavy	66
11	Cars	135
	Medium	20
	Multi Axle Heavy	70
12	Cars	125
	Medium	25
	Multi Axle Heavy	75
17	Cars	145
	Medium	35
	Multi Axle Heavy	50
18	Cars	148
	Medium	40
	Multi Axle Heavy	48
19	Cars	139
	Medium	41
	Multi Axle Heavy	35
20	Cars	120
	Medium	38
	Multi Axle Heavy	36
21	Cars	113
	Medium	0
	Multi Axle Heavy	59
22	Cars	23
	Medium	5
	Multi Axle Heavy	5

Location	Vehicle Category	Number of Passbys
23	Cars	104
	Medium	15
	Multi Axle Heavy	90
24	Cars	72
	Medium	8
	Multi Axle Heavy	63
25	Cars	107
	Medium	31
	Multi Axle Heavy	46
26	Cars	107
	Medium	30
	Multi Axle Heavy	34
27	Cars	105
	Medium	31
	Multi Axle Heavy	48
28	Cars	130
	Medium	21
	Multi Axle Heavy	55
29	Cars	123
	Medium	19
	Multi Axle Heavy	53

Appendix D - CPX Measurement Locations 2019

In 2019, M+P have performed a series of CPX measurements on TII roads, as reported in [15]. In this measurement campaign, nine surface variants have been measured, with three subsections selected for each location (27 sections in total). In Table D 1 below, information about the surface treatments is given. In Figure D.1 the locations are shown on a map.

Table D 1 - Measurement Locations for 2019 CPX Campaign by M+P

location	description	installation date	existing surface
1	M1 Balbriggan – Jn5 to Jn 7	2018	New hot rolled asphalt
2	M1 Dunleer – Jn 11 to Jn 13	1994	Old hot rolled asphalt in ‘good’ condition
3	M4 Dublin – Jn 5 to Jn 7	1994	Old hot rolled asphalt in ‘poor’ condition
4	N2 Cushenstown – Jn R152 to Jn R153	2017	SMA 14
5	M2 Dublin – around Jn 3	2017	Old Stone mastic asphalt 10
6	M2 Dublin – Jn 2 to Jn 3	2006	Old Stone mastic asphalt 14
7	M50 Dublin – Jn 15 to Jn 14	2005	Old porous asphalt
8	M50 Dublin – Jn 6 to Jn 7	2018	New Stone Mastic asphalt with Rubber Filler (RARX)
9	M50 Dublin – Jn 7 tot Jn 9	2008	Old TSCS 14

Figure D.1 - Measurement locations for 2019 CPX campaign by M+P

Appendix E - Road Surface Noise Labelling Procedure

The following Annex II was extracted from the UNECE draft proposal on road surface labelling [16] and describes how SPB measurement results on different locations are combined into a weighted average.

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