Programme "Applied research" under the Norwegian Financial Mechanisms 2014 - 2021

Contract No. NOR/POLNOR/ELANORE/0001/2019-00

ELANORE Improvement of the EU tyre labelling system for noise and rolling resistance

Deliverable D2.2

Final report on the noise measurements on ISO reference surface and on conventional pavements

Main author:	Truls Berge			
Contact details:	Truls.Berge@sintef.no			+47 905 72 026
Co-authors:	Piotr Mioduszewski, Janusz Bohatkiewicz, Maciej Hałucha			
Work Package:	2	Representativeness verification of the tyre/road noise test method proscribed in the Tyre Labelling Directive		
Document type and number:	Technical report, TR13-ELANORE-SINTEF-04-(2022)Rev2			
Date, version and circulation:	30.12.2022 wersja obocza		**D2.2**	**Deliverable**
File name:	TR13-ELANORE-SINTEF-04-(2022) _Rev2.docx			

GDAŃSK UNIVERSITY OF TECHNOLOGY — SINTEF — ekkom

CONTENTS

1 INTRODUCTION

This is the report with the final results from pass-by noise measurements performed on ISO reference road surface on 4 ISO test tracks in Northern Europe, as well as on 5 conventional pavements located on selected trafficked roads in Poland and Norway. The measurements were made according to task 2.5 and 2.6 of Work Package 2 "Representativeness verification of the tyre/road noise test method as proscribed in the Tyre Labelling Directive". A preliminary technical report from measurements done in 2021 was published in 2022 – see TR04-ELANORE-SINTEF-02-(2021) [1].

In Work Package 2 of ELANORE project, a Round Robin Test on a minimum of 3 ISO test tracks was outlined. Only part of the planned program was achieved in 2021, due to some adverse weather conditions on two of three selected test tracks. Therefore, additional measurements on one additional ISO test track were added in the early summer of 2022. Noise measurements were also performed on selected conventional pavements of trafficked roads in Poland and Norway for comparison. This deliverable presents the results of all CPB measurements conducted on ISO test tracks as well as on trafficked roads in Norway and in Poland. Additionally, the results of performed CPX tests on ISO test tracks and of the measurement of L_{EQ}-levels at selected locations are reported here.

2 TESTING PROGRAM

2.1 TEST TYRES

For the controlled pass-by (CPB) noise tests, 4 normal C1 tyre types covering the range of EU label noise values from 67 dB up to 74 dB with 1 dB steps (1 to 3 bars) were selected (within WP1). The selected tyres consist of 2 summer tyres, 1 winter and 1 all-season tyre.

Additionally, one set, consisting of 4 pcs. of "Standard Reference Test Tyre"- SRTT (Uniroyal Tiger Paw) according to the ASTM F2493-14 was included in the test.

The details of all the selected and tested tyres are presented in Table 1. Designations and values given in bold means the selected representative of tyre set when tested with the CPX method, see chapter 4.6.

Table 1. *Description of selected and tested tyres for controlled pass-by measurements*

Manufacturer	Tread pattern	Season	Tyre size	Load index	Speed rating	Remarks	Designation			
Yokohama	Advan Fleva V701	Summer	215/55R17	94	W		T1253	**T1254**	T1255	T1256
Michelin	CrossClimate+	All season	215/55R17	98	W	XL	T1258	**T1259**	T1260	T1261
Bridgestone	Blizzak LM005	Winter	215/55R17	98	V	XL	T1263	**T1264**	T1265	T1266
Evergreen	EH23	Summer	215/55R17	98	V	XL	**T1269**	T1270	T1271	T1272
Uniroyal	Tiger Paw	SRTT	P225/60R16	97	S		**T1273**	T1274	T1275	T1276

Manufacturer	Tread pattern	DOT				Tread rubber hardness				Noise level	FUEL EFFICIENCY	WET GRIP	ROAD NOISE
Yokohama	Advan Fleva V701	3720	**3720**	3620	3720	68	**68**	70	71	**67** dB	C	A	
Michelin	CrossClimate+	4920	**4920**	4920	4920	63	**63**	63	64	**69** dB	C	B	
Bridgestone	Blizzak LM005	4820	**4820**	4820	4720	63	**64**	64	67	**71** dB	C	A	
Evergreen	EH23	**1620**	1620	1620	1620	**71**	70	70	70	**74** dB	E	C	
Uniroyal	Tiger Paw	**4020**	4020	4020	4020	**66**	66	66	66	-	-	-	-

2.2 TEST CONDITIONS

Noise measurements were performed with tyre load and inflation pressure according to the values prescribed in the UNECE Regulation 117 [2], as well as with a modified test condition named Light Test (LT) in this report.

According to Reg.117, the tyre load and inflation pressure depend on the maximum load (load index) of the tyre. Using the formulas given in Reg.117, the tyre load was calculated to 530 kg – uniform for all the tested tyres. The inflation pressure was also identical for all tyres; set to 200 kPa.

In the modified conditions (LT), it was assumed that the tyre load and inflation pressure depend on the particular test vehicle, in this case a Skoda Superb (see chapter 2.4). Thus, the tyre load corresponds to the average load condition of this vehicle: car net weight of 1590 kg (including the driver weighting of 75 kg and 90 % of fuel), plus two passengers (each weighting 85 kg) and 80 kg of luggage. For the used test car, the calculated tyre load was 460 kg, The inflation pressure should fulfill the vehicle manufacturer's requirements. The regular inflation pressure for this Skoda Superb was 230 kPa. Table 2 summarizes the two test conditions.

Table 2. *Tyre load and inflation pressure test conditions for both CPB and CPX measurements*

Test condition	Tyre load [kg]	Inflation pressure [kPa]
R117	530	200
LT	460	230
Change in %	*-13*	*+15*

When analyzing the measurement results from CPX tests performed on 3 ISO test track, a very small influence of used test conditions on the recorded noise levels was observed: 0.2 dB on average. Thus, on the ISO4 test track it was decided, **for CPX tests only**, to reduce the tyre load to 320 kg. These test conditions were designated as LT'. Such tyre load is used in the standardized CPX method [3] and is much more feasible for a regular CPX trailer. Using this load, it was also possible to compare results of CPX measurements performed on conventional pavements using both CPX trailers: GUT's and SINTEF's under Work Package 4 of this project.

The measurements were supposed to be performed with test speeds corresponding to speeds prescribed in Reg.117: 70, 75, 80, 85 and 90 km/h. In addition, speeds at 40, 50 and 60 km/h. The speeds were measured with external radar and in parallel (for parts of the runs at two of the locations) with a light barrier system, using the time between the barrier to estimate the average speed. Thus, it was not always feasible to meet the exact desired speed during the tests. However, according to Reg.117 at least 4 measurements shall be made at speeds below the reference speed (for C1 tyres, 80 km/h) and 4 measurements above the reference, giving a minimum of 8 runs.

For three of the ISO tracks, the number of pass-bys in the speed range of 70 to 90 km/h was 12 for all tyres and test conditions. In addition, two pass-bys around the speeds of 40, 50 and 60 km/h were included in the regression analysis, to establish the noise level at 80 km/h. At one of the test tracks, only a limited number of pass-bys for two of the tyres were achieved (see Table 4 and Table 5).

2.3 INSTRUMENTATION

All pass-by noise levels were measured using the noise measurement equipment from GUT. This includes B&K PULSE sound analyzer, 2 microphones with preamplifiers, a laptop computer, an external radar and a light barrier. Originally, a similar pass-by noise measurement system was planned from SINTEF. This included 2 microphones at the same position as the GUT microphones, only a few centimeters apart – see Figure 1. The average vehicle pass-by speed was calculated based on measured time between two light barriers spaced 30 m apart.

Figure 1. *The position of the microphones (left: GUT's and right: SINTEF's) on both sides of the test track*

Unfortunately, due to technical problems with the software in the laptop, the measured noise levels with the SINTEF equipment were not stable and reliable for two of the test tracks. Thus, it was decided that only the noise levels measured by GUT equipment will be used for analysis.

At ISO2, EKKOM performed measurements of short time A-weighted SEL levels with a microphone positioned 10 m from the center line of the test track and at the height of 4 m (see chapter 4.8).

At each location, the texture (MPD value and g-factor) was measured using the Surface Texture Drone, hired from Müller BBM in Munich – see Figure 2.

Figure 2. *Surface texture drone (left) and conduction of measurements (right)*

Two runs were made on each wheel track at a minimum length of 20 m. In addition to the MPD value, the software consists of an equation to estimate a modelled pass-by noise level at 50 km/h based on the measured MPD value, g-factor (averaged over the measured length) and the average absorption coefficient (for both wheel tracks and average over frequencies between 315 and 1600 Hz). The absorption value is primarily based on measurements made during certification or during periodically checks to prove that the test track fulfils the requirements given in ISO 10844:2014 [4]. If the absorption value is not available, a default value of α = 0.04 is used.

The model has been developed as a part of RRT by VDA in 2016 [5] but has slightly been modified since this project was finalized.

The model is currently as given in this equation:

$$L_{crs} = 60.3 + 27.7 * MPD^{1.5} - 143 \cdot \left(\frac{g \cdot MPD}{(100 \cdot 0.97)}\right)^{4.3} - 36 * \alpha^{0.9} \, [dB] \qquad (1)$$

The formula is somewhat modified from the original equation that was presented in the VDA report [5].

Besides the MPD, g-factor, texture spectra (1.25 to 315 mm) and the estimated noise level, the drone also estimates a CPX level (level at 2.5, 7.5 and 12.5 m at 50 km/h) and estimated rolling resistance for the SRTT test tyre.

2.4 TEST VEHICLE

The controlled pass-by measurements were made with the Skoda Superb (Figure 3) acquired by GUT for the ELANORE project, but also the vehicle to be used as the towing vehicle for future CPX testing at GUT. The test vehicle was equipped with the DGS automatic gearbox. During all pass-bys, the gear selector was set in neutral, and engine was idling.

Figure 3. *Test vehicle: Skoda Superb*

For the CPX measurements, the modernized CPX trailer of GUT, Tiresonic Mk5 was used for all measurements on the ISO tracks, see Figure 4.

Figure 4. *The GUT CPX trailer, Tiresonic Mk5*

Before the Round Robin Test the CPX test trailer, property of GUT, has been completely modernized within the ELANORE project (WP4, Task 4.1) to accommodate test conditions specified in the EU Tyre Labelling procedure (much higher tyre load), to be prepared for the extensive measurement program (to speed-up numerous measurements) and to provide high level measurement precision at all times (new measuring sensors have been purchased and installed).

On the two Norwegian pavements, the CPX measurements were made with both the GUT trailer and the Norwegian trailer. All measurements were made on the same day, under similar conditions; dry roads and air temperatures close to 20 °C.

2.5 TEST LOCATIONS

2.5.1 ISO TRACKS

The measurements were conducted on 4 ISO tracks in Northern Europe. ISO1 to ISO3 all fulfill the requirements of ISO 10844:2014 [4]. ISO4 was at the end of its lifetime when the measurements were made. As shown in Table 3, the MPD value at this track is over the allowed limit of 0.70. The track was resurfaced some weeks after our measurements there. The absorption value for this track was not available. For the rest of the report, the ISO tracks are listed as ISO1, ISO2, ISO3 and ISO4.

Table 3 *Test track information*

Test track	Year of construction	MPD [mm]	Absorption α
ISO1	2015	0.59	0.05
ISO2	2015	0.46	0.03
ISO3	2016	0.47	0.04
ISO4	2014	0.95	-

For all tracks, the MPD values are from measurements using the Surface drone (Figure 2) at the time of noise measurements. The absorption value for ISO1 is from certification measurements done by Müller BBM in March 2021 (approximately 5 months before the noise measurements). For ISO2 the absorption value is from certification measurements by Müller BBM at the same time as the noise measurements were done. Müller BBM did also measure the MPD and absorption values in 2017: MPD = 0.43 and α = 0.031 (0.034 in 2021). Thus, there were no principal changes in the texture and absorption on this test track over a period of 4 years.

2.5.2 CONVENTIONAL PAVEMENTS

CPB measurements on conventional pavements were performed in early summer of 2022 on 5 road sections, 2 in Norway and 3 in Poland. The two road sections in Norway and one section in Poland were under regular traffic conditions. The remaining two road sections in Poland were located on newly built high-speed roads just before they were opened to traffic.

In Norway measurements were done on two road surface test sections located on trafficked roads in southern part of the country:

1. Pavement **<u>Ma11</u>**, located on road Fv1190 close to Skjeberg village. "Ma" is a Norwegian name for a "soft asphalt". It is a dense surface with 11 maximum chipping size. Mostly used on low trafficked roads with few heavy vehicles. This pavement was constructed in the summer of 2021, and due to very low ADT (600), the surface seemed to have very little wear after one year. The location of the measurements was on a flat section of the road and with a speed limit of 80 km/h. Figure 5 shows a photo from the measurement location, Figure 6 - a detail of the road surface texture.

***Figure 5**. Measurement location at Fv1190, Skjeberg (Norway)*

***Figure 6**. Ma11 road surface*

2. Pavement **SMA16**, located on road Fv171 close to Sørum village. This surface was constructed in 2018 and located at a section of the road with ADT approximately around 6000. The test location was on a flat section with a speed limit of 80 km/h. Figure 7 shows a photo from the measurement location and Figure 8 - a detail of the road surface texture.

Figure 7. *Measurement location at Fv171, Sørum (Norway)*

Figure 8. *SMA16 road surface*

In Poland noise measurements were performed on three road surface test sections, two of them (SMA8 and SMA11) were located in northern part of the country and one section (EACC) in eastern part:

1. Pavement **SMA8**, located on a local road close to Bartoszylas village with a speed limit of 90 km/h. This road was repaved in 2019 and is of a very low local traffic only. The surrounding farmlands provided very good acoustics conditions. Figure 9 shows a photo from the measurement location, Figure 10 - a detail of the road surface texture.

Figure 9. *Measurement location at Bartoszylas (Poland)*

Figure 10. *SMA8 road surface*

2. Pavement **SMA11**, located on the newly built S6 high-speed road in northern Poland close to Szemud town. It was built at the turn of 2021/2022, finished in May 2022 but at the time of measurements (July 2022) the road was still closed to traffic. Figure 11 shows a photo from the measurement location, Figure 12 - a detail of the road surface texture.

***Figure 11**. Measurement location at Szemud (Poland)*

***Figure 12**. SMA11 road surface*

3. Pavement **EACC**, located on the newly built S61 high-speed road in north-eastern Poland close to Ełk town. The road surface at the location of test section was laid in 2021 and at the time of measurements (June 2022) the road was still closed to traffic. Figure 13 shows a photo from the measurement location, Figure 14 - a detail of the road surface texture.

Figure 13. *Measurement location at Ełk (Poland)*

Figure 14. *EACC road surface*

3 ACHIEVED MEASUREMENT PROGRAM

3.1 ISO TRACKS

Due to adverse weather conditions (rain/wind), only a part of the planned measurements was achieved. Table 4 shows the completed test program on the four test tracks for CPB measurements and Table 5 for completed CPX measurements. The measurements were conducted between August 20 and August 29, 2021, for ISO1 to ISO3 and 1-2 July 2022 for ISO4.

***Table 4**. Completed test program for controlled pass-by measurements*

Tyre no	Manufacturer	Tread pattern	Test location	Test condition
1	Yokohama	Advan Fleva V701	ISO1	R117
			ISO2	R117+LT
			ISO3	R117
			ISO4	R117+LT
2	Michelin	CrossClimate+	ISO1	R117
			ISO2	R117+LT
			ISO3	R117*
			ISO4	R117+LT
3	Bridgestone	Blizzak LM005	ISO1	R117
			ISO2	R117+LT
			ISO3	-
			ISO4	R117+LT
4	Evergreen	EH23	ISO1	R117
			ISO2	R117+LT
			ISO3	-
			ISO4	R117+LT
5	Uniroyal	Tiger Paw (SRTT)	ISO1	R117
			ISO2	R117+LT
			ISO3	-
			ISO4	R117+LT

* At ISO3, due to rainy weather, only a limited number of pass-bys was reached with tyre 2.

***Table 5**. Completed test program for CPX measurements*

Tyre no	Manufacturer	ISO1		ISO2		ISO3		ISO4	
		R117	LT	R117	LT	R117	LT	R117	LT’
1	Yokohama	x		x	x	x	x	x	x
2	Michelin	x		x	x	x	x	x	x
3	Bridgestone	x		x	x	x	x	x	x
4	Evergreen	x		x	x	x	x	x	x
5	SRTT Uniroyal	x		x	x	x	x	x	x
6	Dębica	x		x	x	x		x	x
7	Kenda	x		x	x	x		x	x
8	Vredestein	x		x	x	x	x	x	x
9	Continental	x		x	x	x	x	x	x
10	Momo	x		x	x	x		x	x
11	Avon AV4	x		x	x	x		x	x

3.2 CONVENTIONAL ROADS

On the Norwegian and Polish roads, both the tests according to Reg.117 and the Light Test (LT’ in case of CPX tests) was performed both for CPB and CPX measurements with some exceptions due to rain fall. The completed test program was shown in Table 6. Measurements were conducted in the time period from May 31st to July 29th, 2022. It should be pointed out that the CPX tests performed on conventional pavements (shadowed in Table 6) are not in scope of this Deliverable. They were done as part of Work Package 4 of this project.

***Table 6**. Completed test program on conventional roads*

Tyre no	Manufacturer	CPB										CPX (under the WP4)									
		MA11		SMA8		SMA11		SMA16		EACC		MA11		SMA8		SMA11		SMA16		EACC	
		R117	LT	R117	LT	R117	LT	R117	LT	R117	LT	R117	LT’	R117	LT’	R117	LT’	R117	LT’	R117	LT’
1	Yokohama	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2	Michelin	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3	Bridgestone	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
4	Evergreen	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
5	SRTT Uniroyal	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
6	Dębica											x	x	x	x	x	x	x	x	x	
7	Kenda											x	x	x	x	x	x	x	x	x	
8	Vredestein											x	x	x	x	x	x	x	x	x	
9	Continental											x	x	x	x	x	x	x	x	x	
10	Momo											x	x	x	x	x	x	x	x	x	
11	Avon AV4											x	x	x	x	x	x	x	x	x	

4 MEASUREMENT RESULTS ON ISO TEST TRACKS

4.1 ESTIMATION OF PASS-BY LEVELS BASED ON SURFACE DRONE MEASUREMENTS

Table 7 shows the estimations for noise levels at 50 km/h for three of the ISO tracks. Since the absorption value of ISO4 was not available, and the MPD values above the limit of 0.70, the modelled pass-by level was not available for this test track.

Table 7. *Modelled pass-by noise levels based on drone measurements*

Test track	Modelled pass-by level at 50 km/h [dBA]
ISO1	62.4
ISO2	63.9
ISO3	63.7
ISO4	n/a

The table indicates that there is not a large noise difference between the ISO tracks, based on the model. The difference is around 1.5 dB between ISO1 and ISO2. The estimated sound level is sensitive to the absorption level, as shown in equation 1. If for example the value of α at ISO3 is 0.03 instead of the value of 0.04, the level is estimated to be 64.2 dB. Equally, if α = 0.06 (still under the legal limit of 0.08) the estimated level will be 62.9 dB. The range between the value of α = 0.03 and 0.06 is then 1.3 dB, which is in the same order as the differences between the measured ISO tracks.

4.2 TEMPERATURE MEASUREMENTS AND CORRECTIONS

In general, both air and road surface temperatures were measured both at the start and at the end of CPB measurements for the R117 and the LT. However, due to practical reasons, only temperatures at the start of some of the tests were recorded. For these tests, the same air and road surface temperatures have been used for corrections of all runs.

According to Reg. 117, the road surface temperatures below the reference temperature of 20 °C shall be corrected with a negative slope of -0.06 dB/°C and with -0.03 dB/°C for temperatures above 20 °C.

The pass-by levels were also corrected for air temperatures according to the proposal given in ISO/DTS 13471-2 [6]. For C1 tyres there is a linear relationship between the pass-by noise level and the air temperature: -0.10 dB/°C for the whole temperature range (from +5 to +35 °C) for dense surfaces, such as the ISO track surface. For all test conditions on the three test tracks, the road surface temperature was always above 20 °C, thus the correction term -0.03 dB/°C was used for all pass-bys.

For ISO4, a third correction procedure was available. In a publication by the tyre industry, ETRTO, a revised temperature correction procedure for summer tyres (C1) and winter tyres (3PMSF) [7]. This proposal is expected to be proposed as an amendment to R117 in 2023. It is still based on road surface temperature, as ETRTO states that shifting to air temperature will introduce additional uncertainties that should be avoided. The reason being that they have found different relationship between air and road surface temperatures, depending on location of the test track.

The proposed temperature correction is non-linear, and the correction is shown in equation 2:

$$L_{corr} = -K1 \times LOG\left(\frac{\vartheta_{ref} + K2}{\vartheta_{test} + K2}\right) \qquad (2)$$

	Summer	3PMSF
K1	2.18	1.35
K2	0	2.29
ϑref	20	20

For the results on ISO4, the measured noise levels have been corrected with all 3 available procedures, as shown in Table 8.

A more detailed presentation and discussion on the use of different temperature compensation procedures is found in the Technical Report TR11-ELANORE-SINTEF-03-(2022) [8].

Table 8 gives an overview of the measured air and road surface temperatures for CPB tests as well as the correction values for each of the two correction methods (R117 and ISO) on the three ISO tracks. Negative sign (for ISO corrections only) means that the corrected values are lower than the measured value. If the first value in the range of temperature is higher than the last, this indicates that the temperature sank during the testing period. Note that for ISO4, all road surface temperatures are always above 20 °C, thus the correction term according to the ETRTO (equation 2) is almost similar to the values given for R117 and road surface correction. If the temperature had been below 20 °C, the correction according to ETRTO would have been different to the present R117 corrections. Negative values mean that the measured values are reduced according to the values in the table.

Table 8. *Road surface and air temperatures on the 4 ISO tracks*

ISO1	R117 test condition			
Tyre set	**Road surface temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**
Yokohama	24.9 - 27.6	0.15 - 0.23	17.3 - 19.3	-0.37 - (-0.07)
Michelin	30.3	0.31	20.8	0.08
Bridgestone	35.0	0.45	20.8	0.08
Evergreen	41.0 - 39.8	0.63 - 0.59	23.8 - 22.8	0.38 - 0.28
SRTT	38.6	0.56	23.8	0.38

ISO2	R117 test condition				LT test condition			
Tyre set	**Road surf. temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**	**Road surf. temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**
Yokohama	29.8	0.29	19.3	-0.07	21.1 - 20.2	0.03 - 0.00	12.8 - 12	-0.72 - (-0.8)
Michelin	33.4	0.40	20.8	0.08	22.6 - 22.1	0.08 - 0.06	14.4 - 12.6	-0.56 - (-0.74)
Bridgestone	37.4	0.52	22.6	0.26	24.7 - 23.0	0.14 - 0.09	19.3 - 15.8	-0.07 - (-0.42)
Evergreen	38.4 - 34.7	0.55 - 0.44	22.6 - 20.3	0.26 - 0.03	30.0 - 25.8	0.30 - 0.17	21.6 - 17.6	0.16 - (-0.24)
SRTT	25.0 - 23.0	0.15 - 0.09	22.9 - 21.8	0.29 - 0.18	31.8 - 30.3	0.35 - 0.31	21.6 - 21.3	0.16 - 0.13

ISO3	R117 test condition			
Tyre set	**Road surface temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**
Yokohama	22.0 - 24.2	0.06 - 0.12	16.9 - 17.3	-0.31 - (-0.27)
Michelin	24.2	0.12	17.3	-0.28

ISO4	R117 test condition				LT test condition			
Tyre set	**Road surf. temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**	**Road surf. temp. [°C]**	**Correction ΔL [dB]**	**Air temp. [°C]**	**Correction ΔL [dB]**
Yokohama	34.3 - 33.3	0.43 - 0.40	20.3	0.03	33.5 - 35.0	0.41-0.45	16.8 - 19.3	-0.32 - (-0.07)
Michelin	30.8 - 35.2	0.32 - 0.46	15.7 - 18.8	-0.43 - (-0.12)	29.2	0.28	15.7 - 17.4	-0.43 - (-0.26)
Bridgestone	37.3 - 35.8	0.52 - 0.47	22.8 - 21.8	0.28 - 0.18	35.4 - 33.2	0.46 - 0.40	20.3 - 18.4	0.03 - (-0.16)
Evergreen	41.6 - 38.0	0.65 - 0.54	24.1 - 22.7	0.41 - 0.27	34.4 - 34.6	0.43 - 0.44	18.0 - 19.2	-0.20 - (-0.08)
SRTT	31.8 - 31.0	0.35 - 0.33	20.0 - 19.9	0 - (-0.01)	35.9 - 35.4	0.48 - 0.46	20.1 - 19.0	0.01 - (-0.1)

4.3 CONTROLLED PASS-BY MEASUREMENTS

The results of controlled pass-by measurements are presented for three different cases:

1) with no correction for temperature,
2) with correction using the R117 definition (road surface temperature),
3) with correction based on ISO/DTS 13471-2 (air temperature).

Since all pass-by measurements were made in a speed range from 40 to 90 km/h, all the sound levels in this speed range were used for the linear regression to establish the sound level at the reference speed of 80 km/h.

In Table 9 all the final noise levels at the three ISO tracks at the speeds of 50 and 80 km/h are presented for the uncorrected levels, the corrected levels according to R117 and corrected according to the ISO/DTS. All levels are calculated from the linear regression curves.

Table 9. *CPB levels at 50 and 80 km/h for 4 ISO tracks*

ISO1	**R117, 50 km/h**			**R117, 80 km/h**		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	64.5	64.7	64.2	71.1	71.3	71.0
Michelin	65.0	65.3	65.1	72.7	73.0	72.8
Bridgestone	65.2	65.6	65.3	71.9	72.3	71.9
Evergreen	64.1	64.7	64.5	71.5	72.1	71.8
SRTT	66.9	67.5	67.3	74.6	75.1	75.0
Average	**65.1**	**65.6**	**65.3**	**72.4**	**72.8**	**72.5**
ISO2	**R117, 50 km/h**			**LT, 50 km/h**		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	64.8	65.1	64.8	65.3	65.3	64.5
Michelin	65.9	66.3	66.0	66.3	66.3	66.7
Bridgestone	65.9	66.5	66.1	66.2	66.3	65.9
Evergreen	65.2	65.7	65.2	65.3	65.5	65.1
SRTT	68.2	68.3	68.4	67.9	68.2	68.0
Average	**66.0**	**66.3**	**66.1**	**66.2**	**66.3**	**66.0**
ISO2	**R117, 80 km/h**			**LT, 80 km/h**		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	71.9	72.2	71.8	72.2	72.2	71.5
Michelin	74.0	74.4	74.1	74.1	74.2	74.7
Bridgestone	73.0	73.6	73.3	73.3	73.5	73.2
Evergreen	72.8	73.3	72.9	73.1	73.4	73.1
SRTT	76.0	76.1	76.2	76.1	76.4	76.2
Average	**73.5**	**73.9**	**73.7**	**73.8**	**73.9**	**73.7**

Table 9 cnt. *CPB levels at 50 and 80 km/h for 4 ISO tracks*

ISO3	R117, 50 km/h			R117, 80 km/h		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	63.1	63.2	62.9	69.9	70.0	69.6
Michelin	66.9	66.3	66.6	72.5	72.6	72.2
ISO4	**R117, 50 km/h**			**LT, 50 km/h**		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	65.4	65.8	65.4	65.0	65.4	64.8
Michelin	66.8	67.3	66.5	66.5	66.8	66.1
Bridgestone	66.8	67.3	67.0	67.1	67.5	67.0
Evergreen	65.5	66.1	65.9	66.0	66.4	65.8
SRTT	68.8	69.1	68.8	68.3	68.7	68.2
Average	**66.7**	**67.1**	**66.7**	**66.6**	**67.0**	**66.4**
ISO4	**R117, 80 km/h**			**LT, 80 km/h**		
Tyre set	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**	**No correction [dB(A)]**	**R117 corrected [dB(A)]**	**ISO corrected [dB(A)]**
Yokohama	71.6	72.0	71.6	71.4	71.8	71.2
Michelin	74.0	74.4	73.8	73.7	74.0	73.4
Bridgestone	73.5	74.0	73.7	73.9	74.3	73.8
Evergreen	72.6	73.2	73.0	72.8	73.2	72.7
SRTT	76.3	76.6	76.3	75.9	76.4	75.8
Average	**73.6**	**74.0**	**73.7**	**73.5**	**73.9**	**73.4**

In Figure 15 to Figure 17, the results for R117 test conditions are shown for the three situations: no correction, R117 correction (road surface temperature) and ISO correction (air temperature correction). Speeds 50 and 80 km/h. In the Figure 16 (for 50 km/h), the estimated noise level by the surface drone (see Table 7) is included, as well as the average level for the 5 tyres. In Figure 16, for the speed of 80 km/h, the labelled values given by the manufacturer are included, as they are based on the same measurement condition.

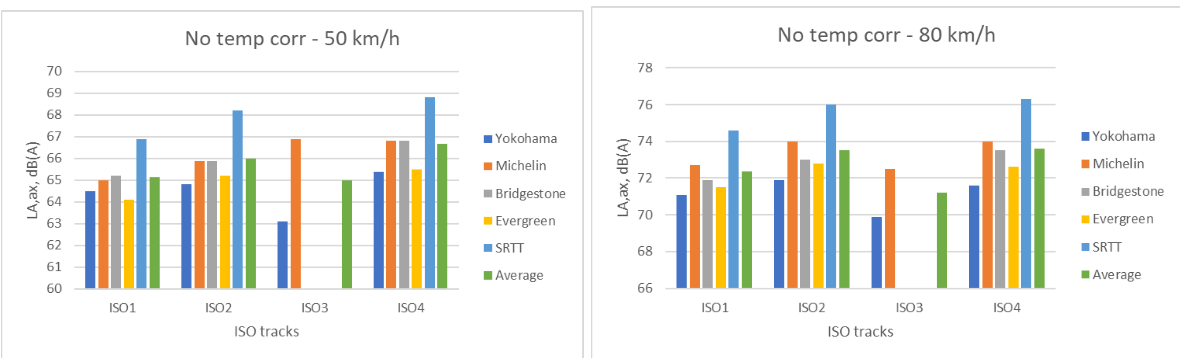

Figure 15*.* *R117 test condition – No temperature correction. Speeds: 50 (left) and 80 km/h (right)*

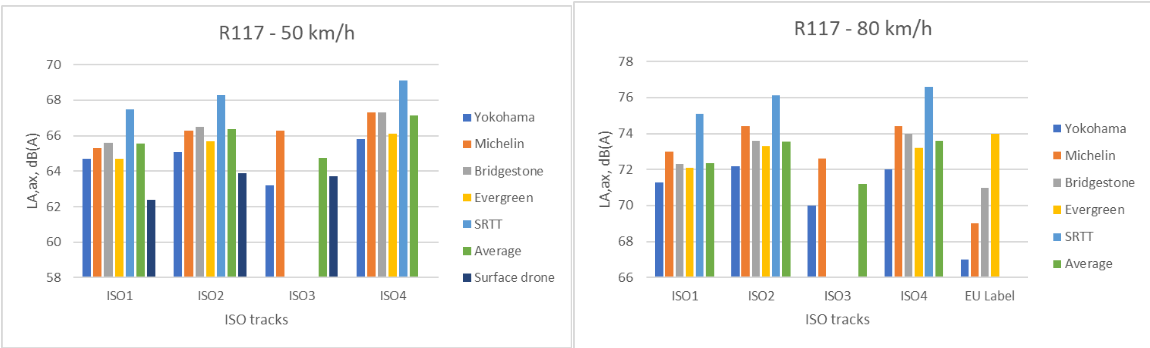

Figure 16. *R117 test condition – R117 temperature correction. Speed: 50 (left) and 80 km/h (right)*

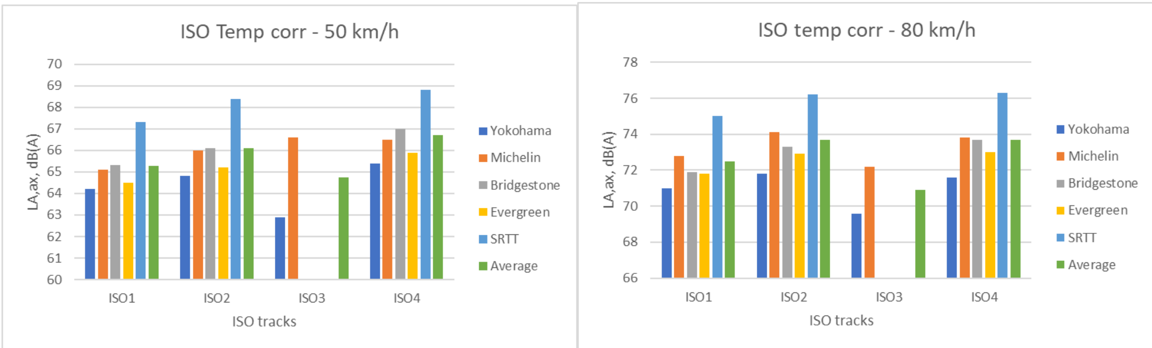

Figure 17. *R117 test condition – ISO temperature correction. Speed: 50 (left) and 80 km/h (right)*

In Table 10 the measured noise levels, including average and spread, are shown for the 4 ISO tracks.

Table 10. *CPB levels at 50 and 80 km/h for 4 ISO tracks according to R117 test procedure*

Tyre	Sound pressure level in dB(A) – Speed 50 km/h					
	ISO1	ISO2	ISO3	ISO4	Average	Spread
Yokohama	64.7	65.1	63.2	65.8	64.7	2.6
Michelin	65.3	66.3	66.3	67.3	66.3	2.0
Bridgestone	65.6	66.5	-	67.3	66.5	1.7
Evergreen	64.7	65.7	-	66.1	65.5	1.4
SRTT	67.5	68.3	-	69.1	68.3	1.6
Tyre	**Sound pressure level in dB(A) – Speed 80 km/h**					
	ISO1	**ISO2**	**ISO3**	**ISO4**	**Average**	**Spread**
Yokohama	71.3	72.2	70.0	72.0	71.4	2.0
Michelin	73.0	74.4	72.6	74.4	73.6	1.8
Bridgestone	72.3	73.6	-	74.0	75.5	1.7
Evergreen	72.1	73.3	-	73.2	72.9	1.2
SRTT	75.1	76.1	-	76.6	75.9	1.5

The main conclusion from these measurements is that the noise ranking based on *measured levels* does not change with either the ISO track used for measurement, or by the temperature correction procedure used, or by the test condition used (R117 or LT).

Compared to the estimated noise level from the surface drone, the average noise levels at ISO1 for all 5 tyres are lower than for ISO2 and ISO3, which is consistent with the estimated noise level for ISO1-ISO3. All levels at 50 km/h are higher on ISO4 (50 km/h), which may be caused by the MPD value being higher than the allowed maximum according to ISO 10844:2014. However, this is not the case at 80 km/h, so the higher MPD values may not be the main contribution to the differences.

The ranking of noise levels measured according to R117, corrected for road surface temperature, and compared to the labelled values are shown in Table 11. In this table, the calculated label values based on the measured noise levels are included. Only for the Bridgestone tyre there is an agreement with the label given by the manufacturer and the label value on ISO1.

The Yokohama tyres are the most silent tyres on all ISO tracks and the Michelin tyre has the highest level, when the SRTT is excluded from the comparison. Only for the Bridgestone tyre on ISO1, there is an agreement with the label value as given by the tyre manufacturer. The highest difference between the given label value and measured value is 4 dB for 2 of the tyres. This difference is to be expected as previous round-robin tests have shown a variation between ISO tracks in the range of 4-5 dB.

Table 11. *Tyre noise ranking on ISO1, ISO2 and ISO4, compared to the noise label values as given by the manufacturer*

Tyre	"Label value" ISO1 dB(A)	Ranking	"Label value" ISO2 dB(A)	Ranking	"Label value" ISO4 dB(A)	Ranking	EU label value dB(A)	Ranking
Yokohama	70	1	71	1	71	1	67	1
Michelin	72	4	73	4	73	4	69	2
Bridgestone	71	3	72	3	73	3	71	3
Evergreen	71	2	72	2	72	2	74	4

In chapter 4.2, a revised temperature correction procedure for R117 was presented (ETRTO).

Table 12 summarizes the range of temperatures measured in the four ISO tracks.

Table 12. *Range of air and road surface temperatures on the ISO tracks*

ISO track	Air temperature range [°C]	Road surface temperature range [°C]
ISO1	17.3 – 23.8	24.9 – 41.0
ISO2	12.0 – 22.9	20.2 – 38.4
ISO3	16.9 – 17.3	22.0 – 24.2
ISO4	15.7 – 24.1	30.8 – 41.6

In Figure 18, the measured noise levels on ISO4 have been corrected according to the present version in R117, by the ISO standard and by the new revised method. The ranking of tyres does not depend on the correction procedure applied, except a minor difference between two of the tyres (Michelin and Bridgestone) when using the ISO air temperature correction procedure. As Table 12 shows, there are quite high differences between the air and road surface temperatures for the 4 ISO tracks.

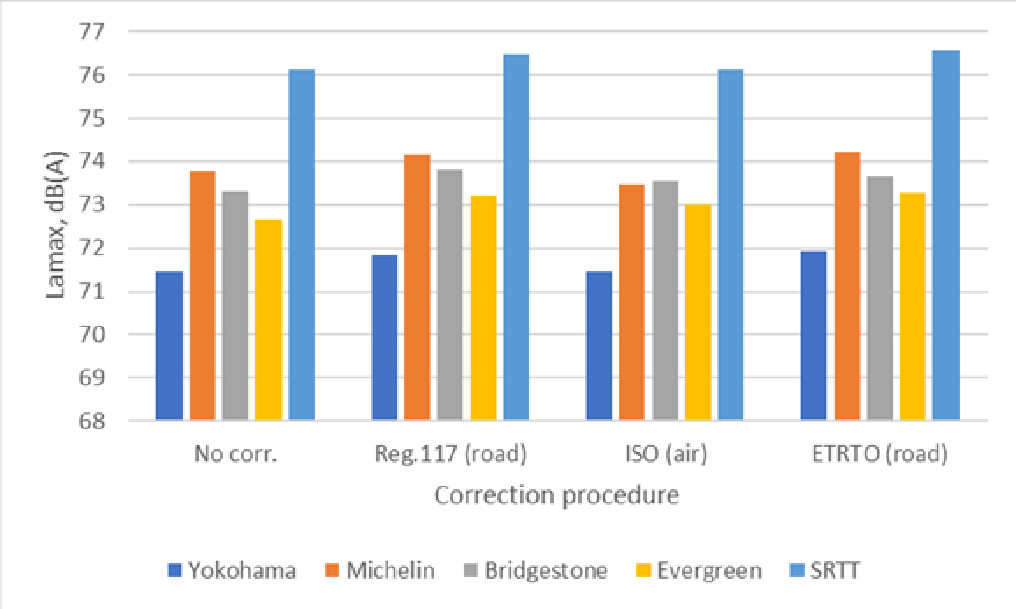

Figure 18. *Measured noise levels on ISO4, with 3 different temperature correction procedures, compared to non-corrected values.*

For all 4 ISO tracks, the road surface temperature was above the reference temperature of 20 °C, which means that the corrected levels are always **higher** than the uncorrected. Since the proposed non-linear correction proposal from ETRTO are almost identical to the present correction procedure in Reg.117 for temperatures above the reference temperature, the corrected levels between the existing and proposed procedure are almost equal (Figure 18).

In general, there is a clear understanding that the uncertainties due to the influence of temperature can be reduced by introducing an improved correction procedure as proposed either by the STEER project or by ETRTO. In the STEER report [9], it is estimated that the uncertainty related to the temperature corrections can be reduced by one third, from a standard deviation of 0.59 to 0.34 dB.

4.4 INFLUENCE OF TYRE LOAD AND TYRE INFLATION PRESSURE

As shown in Table 2, the "Light Test" (LT) was made with a decrease of tyre load of 13 % and an increase of the tyre inflation pressure of 15 %.

Table 13 shows the changes in noise levels on ISO4, for the two conditions: R117 and LT.

Table 13. *Influence of tyre load and tyre inflation pressure on ISO4*

Tyre	Season	R117 [dB]	LT [dB]	Difference [dB]
Yokohama	Summer	72.0	71.8	-0.2
Michelin	All-season	74.4	74.0	-0.4
Bridgestone	Winter	74.0	74.3	0.3
Evergreen	Summer	73.2	73.2	0.0
Uniroyal	SRTT	76.6	76.4	0.2

This is consistent with the results on the other ISO test tracks, see Table 9. The differences are so small, within the uncertainty of the measuring method. The LT does not change the ranking of the tyres.

4.5 NOISE DIFFERENCES LEFT AND RIGHT SIDE

R117 specifies a measurement on each side of the vehicle. Thus, it is possible to investigate any significant noise differences between the tyres mounted on the left and on the right side of the vehicle. To eliminate any differences due to the wheel tracks itself, the measurement should have been made with the vehicle running in both directions on the track. However, the setup of the instrumentation (light barriers and radar) did not allow measurements in each direction. However, it is assumed that there were only minor differences between the wheel tracks, and any significant differences would be related to the tyres themselves.

In Table 14, the measured noise differences and the standard deviation between left and right side of the vehicle is listed for 3 of the ISO tracks, where all R117 conditions were met.

Table 14. *Difference between left and right side of the vehicle during CPB. Positive values means that the level at the left side is higher than on the right side.*

Track	Yokohama		Michelin		Bridgestone		Evergreen		SRTT	
	Average	Stdev	Average	Stdev	Average	Stdev	Average	Stdev	Average	Stdev
ISO1	0.40	0.37	0.51	0.31	0.22	0.42	-0.29	0.50	1.66	0.63
ISO2	0.34	0.50	0.55	0.35	0.76	0.44	0.95	0.29	1.63	0.76
ISO4	-0.21	0.38	0.47	0.30	-0.06	0.39	-0.31	0.59	1.63	1.00

The table shows that there is a clear difference between the left and right side for the SRTT tyres, which mainly is caused by different noise performance of the tyres of the left and right side. For the other tyres, there are only minor differences, mostly within the expected uncertainties of a CPB test. The differences of left and right side of the SRTT tyre seems to be consistent and is approximately the same for all 3 ISO test tracks. This is presumably caused by a non-symmetric tread pattern of the SRTT tyre. The tyre is also equipped with an arrow showing the rolling direction

4.6 CPX MEASUREMENTS

The CPX tests on the selected ISO test tracks were planned as an additional measurement campaign to vehicle coast-by noise tests performed according to the Regulation 117. They were conducted under the same test conditions as were used in the Round Robin Test.

4.6.1 TEST TYRES

For the purpose of noise tests performed in ELANORE project, 9 different C1 tyre types (4 of them in sets of 4 tyres) covering the range of EU label noise values from 66 dB up to 74 dB with 1 dB step (1 to 3 noise bars) were selected and purchased within WP1. Only one selected tyre from each tyre set was tested using the CPX method. The selected tyres consisted of 4 summer tyres, 3 winter and 2 all-season tyres. Additionally, one set consisting of 4 pcs. of "Standard Reference Test Tyre" - SRTT (Uniroyal Tigerpaw) according to the ASTM F2493-14 was also purchased and one tyre was also selected from this tyre set for CPX measurements. Furthermore, the standard reference tyre (Avon Supervan AV4), designated H1 according to the technical specification ISO/TS 11819-3:2017 [10] was used in CPX tests.

The details of all the selected and tested tyres were presented in Table 15.

***Table 15**. Description of the selected tyres for CPX tests*

Designation	Manufacturer	Tread pattern	Season	Tyre size	Load index	Speed rating	Remarks	DOT	Tread rubber hardness	FUEL EFFICIENCY	WET GRIP	ROAD NOISE	Noise level
T1252	Dębica	PRESTO UHP	Summer	215/55R17	94	W		**3216**	**74**	E	C		**66** dB
T1254	Yokohama	Advan Fleva V701	Summer	215/55R17	94	W		**3720**	**68**	C	A		**67** dB
T1257	Kenda	KR501	Winter	215/55R17	98	V	XL	**2420**	**61**	E	C		**68** dB
T1259	Michelin	CrossClimate+	All season	215/55R17	98	W	XL	**4920**	**63**	C	B		**69** dB
T1262	Vredestein	Ultrac Satin	Summer	215/55R17	98	W	XL	**1021**	**65**	B	A		**70** dB
T1264	Bridgestone	Blizzak LM005	Winter	215/55R17	98	V	XL	**4820**	**64**	C	A		**71** dB
T1267	Continental	AllSeasonContact	All season	215/55R17	98	H	XL	**1121**	**63**	A	B		**72** dB
T1268	Momo	W-2 NORTH POLE	Winter	215/55R17	98	V	XL	**2520**	**67**	E	C		**73** dB
T1269	Evergreen	EH23	Summer	215/55R17	98	V	XL	**1620**	**71**	E	C		**74** dB
T1273	Uniroyal	Tiger Paw	SRTT	P225/60R16	97	S		**4020**	**66**	-	-	-	-
T1182	Avon	Supervan AV4	AAV4	195R14C	106/104	N		**4814**	**71**	-	-	-	-

4.6.2 TEST CONDITIONS

CPX noise measurements were performed with tyre load and inflation pressure according to the values prescribed in the Regulation 117 on 4 ISO test tracks. Additional measurements with modified test conditions (LT) were performed on 2 tracks (11 tyres on ISO2 and 7 tyres on ISO3) and with LT' test conditions on ISO4 test track. The test conditions were comparable to the conditions when tested the vehicle pass-by noise at ISO test tracks.

The tyre load and inflation pressure according to the UNECE Regulation No.117 was correspondingly 530 kg and 200 kPa, uniform for all the selected tyres. In the modified test conditions designated LT, the tyre load was 460 kg while the inflation pressure was 230 kPa. In the LT' conditions tyre load was reduced to 320 kg while the inflation pressure remained unchanged (230 kPa). The measurements were performed with two test speeds of 50 and 80 km/h.

4.7 CPX MEASUREMENT RESULTS

All measurement results presented in this chapter of this technical report were corrected for speed and temperature but were not corrected for tyre rubber hardness. The corrections applied were calculated according to the Annex of the ISO 11819-2:2017 [3] standard.

4.7.1 NOISE LEVELS

The results of measurements, A-weighted sound pressure levels of the average of front and rear microphones, were presented in Table 16, as well as in Figure 19 and in Figure 20 (for the speed of 50 and 80 km/h correspondingly). Please observe that not all tyres were tested on ISO track 3 test track due to unpredicted unsatisfactory weather conditions (rainfalls).

Table 16. *Noise levels of tested tyres on four different ISO test tracks*

Tyre	Sound Pressure Level in dB(A)											
	50 km/h						80 km/h					
	ISO1	ISO2	ISO3	ISO4	**Average**	***Spread***	ISO1	ISO2	ISO3	ISO4	**Average**	***Spread***
T1252	85.4	86.3		86.5	**86.1**	***1.0***	92.5	93.9		93.5	**93.3**	***1.4***
T1254	84.6	84.7	84.7	85.1	**84.7**	***0.5***	90.8	91.7	91.2	91.7	**91.4**	***0.9***
T1257	85.3	86.4		85.9	**85.8**	***1.0***	91.4	92.4		91.9	**91.9**	***1.0***
T1259	84.4	85.6	85.2	85.7	**85.2**	***1.4***	91.4	92.9	92.5	92.7	**92.4**	***1.5***
T1262	84.6	84.9	86.6	86.2	**85.6**	***2.1***	91.3	92.1	94.0	93.2	**92.7**	***2.7***
T1264	85.4	86.9	85.8	87.7	**86.4**	***2.3***	91.6	92.9	91.6	93.8	**92.5**	***2.2***
T1267	85.7	86.7	86.2	87.7	**86.6**	***2.0***	93.4	93.4	92.5	94.5	**93.4**	***2.0***
T1268	87.3	88.4		88.6	**88.1**	***1.4***	95.3	95.6		95.6	**95.5**	***0.3***
T1269	85.1	85.4	84.1	85.7	**85.1**	***1.6***	92.6	93.2	91.8	92.7	**92.6**	***1.3***
T1273	86.9	89.1	88.1	88.3	**88.1**	***2.2***	92.2	95.9	94.7	94.7	**94.4**	***3.7***
T1182	89.0	90.5		90.4	**90.0**	***1.5***	95.5	96.9		97.1	**96.5**	***1.6***

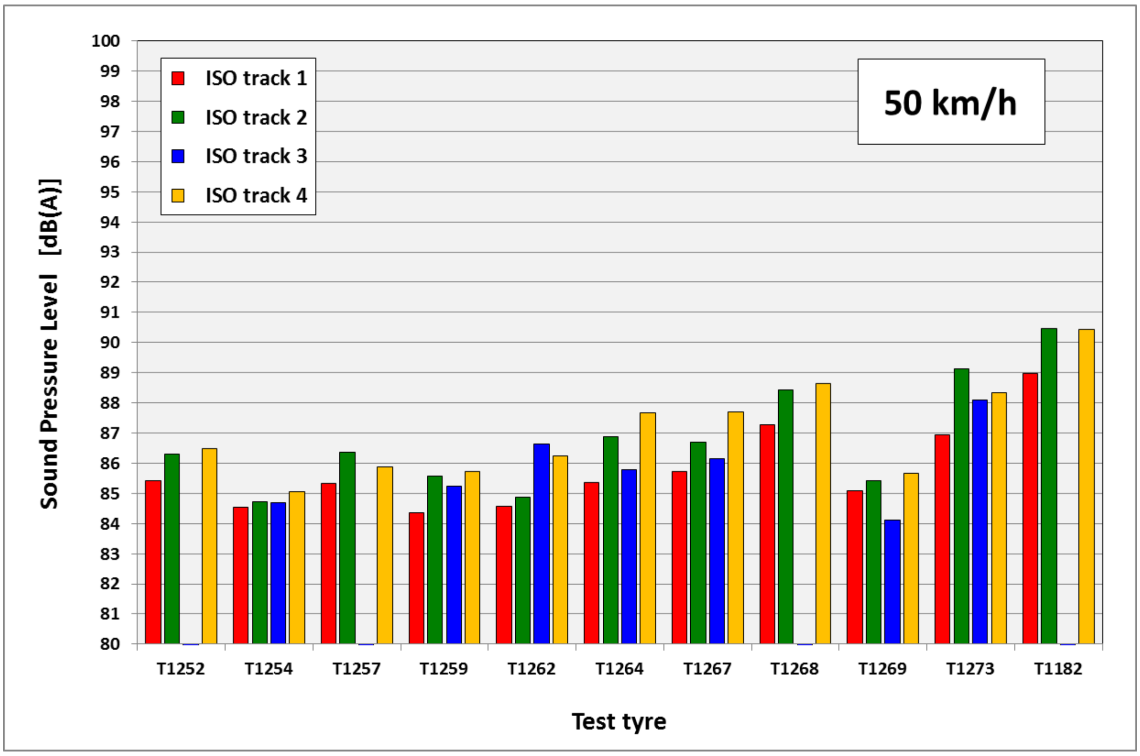

Figure 19. *Noise levels of tested tyres on different ISO test tracks for the speeds of 50 km/h*

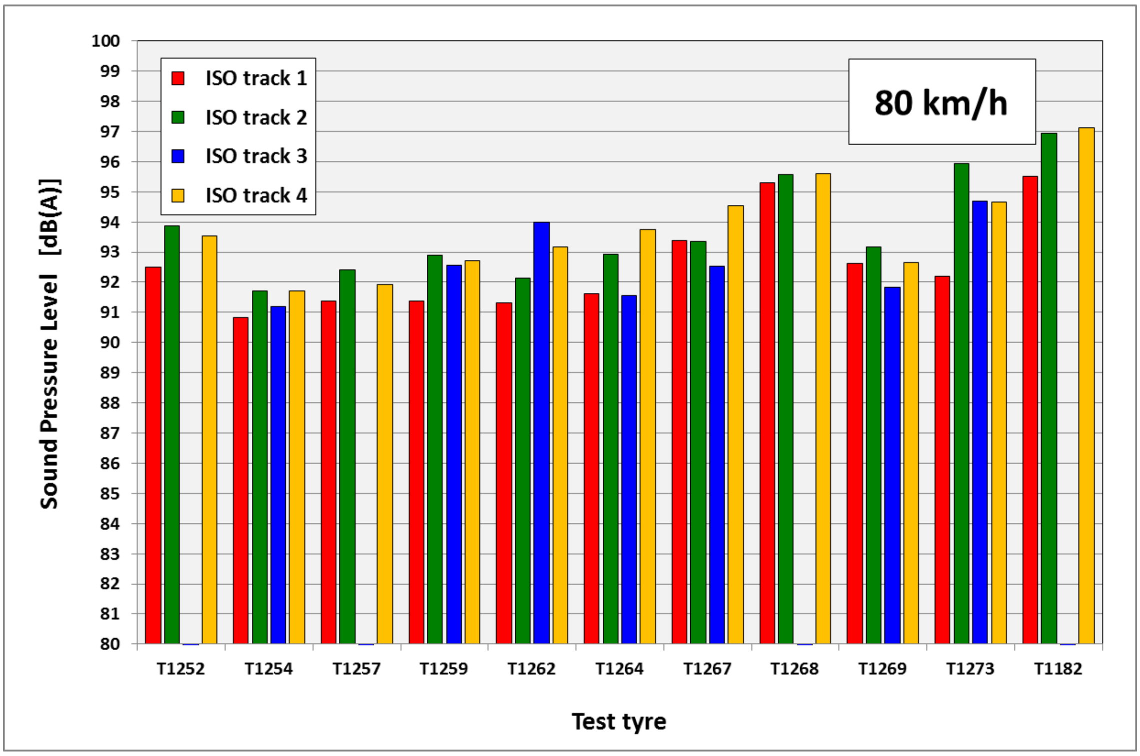

Figure 20. *Noise levels of tested tyres on different ISO test tracks for the speeds of 80 km/h*

The influence of different test conditions (tyre load and inflation pressure) on measured sound pressure levels were presented in Table 17.

Table 17. *Noise levels of tested tyres on ISO2 and ISO4 under different tyre load and inflation pressure conditions*

Tyre	Sound Pressure Level in dB(A) - ISO test track 2						Sound Pressure Level in dB(A) - ISO test track 4					
	50 km/h			80 km/h			50 km/h			80 km/h		
	Reg.117	LT	Difference	Reg.117	LT	Difference	Reg.117	LT'	Difference	Reg.117	LT'	Difference
T1252	86.3	86.3	0.0	93.9	93.8	0.0	86.5	86.2	0.2	93.5	93.3	0.3
T1254	84.7	84.3	0.4	91.7	91.4	0.3	85.1	84.0	1.0	91.7	90.6	1.1
T1257	86.4	85.7	0.6	92.4	92.3	0.1	85.9	84.3	1.6	91.9	91.5	0.4
T1259	85.6	85.3	0.2	92.9	92.7	0.2	85.7	85.3	0.4	92.7	92.6	0.1
T1262	84.9	85.4	-0.5	92.1	93.1	-0.9	86.2	85.3	0.9	93.2	92.6	0.6
T1264	86.9	86.3	0.5	92.9	92.6	0.4	87.7	87.1	0.5	93.8	93.5	0.2
T1267	86.7	86.4	0.2	93.4	93.1	0.3	87.7	86.5	1.2	94.5	93.4	1.1
T1268	88.4	87.5	0.9	95.6	95.1	0.5	88.6	87.6	1.1	95.6	94.8	0.8
T1269	85.4	85.4	0.1	93.2	93.1	0.1	85.7	84.9	0.7	92.7	91.9	0.8
T1273	89.1	88.0	1.1	95.9	95.1	0.9	88.3	87.3	1.0	94.7	94.3	0.3
T1182	90.5	90.3	0.2	96.9	98.1	-1.2	90.4	89.5	0.9	97.1	98.3	-1.2
max	90.5	90.3	1.1	96.9	98.1	0.9	90.4	89.5	1.6	97.1	98.3	1.1
min	84.7	84.3	-0.5	91.7	91.4	-1.2	85.1	84.0	0.2	91.7	90.6	-1.2
avg	**86.8**	**86.5**	**0.3**	**93.7**	**93.7**	**0.1**	**87.1**	**86.2**	**0.9**	**93.8**	**93.4**	**0.4**
std.dev.			***0.5***			***0.6***			***0.4***			***0.6***

The average difference between the Reg.117 and LT test conditions is small, in the range of 0.1 - 0.3 dB, between Reg.117 and LT' slightly higher 0.4 - 0.9 dB. But the calculated standard deviation is comparable for 2 test speeds and 2 ISO test tracks: from 0.4 to 0.6 dB.

On ISO2 test track, depending on the tested tyre for the speed of 80 km/h the difference is from -1.2 up to 0.9 dB. For 50 km/h the range is similar: from -0.5 to 1.1 dB. The difference between the Reg.117 and the Modified conditions for 8 of 9 C1 tyres and for SRTT tyre is positive, while for one summer C1 tyre and for the Avon H1 reference tyre is negative. Similar behavior of tyres can be observed on ISO4 test track: for the speed of 80 km/h, depending on the tyre, the difference is from -1.2 up to 1.1 dB, for 50 km/h - from 0.2 to 1.6 dB. The difference between the Reg.117 and the LT' conditions for all 9 C1 tyres and for SRTT tyre is positive, while for the Avon H1 reference tyre is negative.

4.7.2 TYRE RANKING

It was expected that the tyre ranking according to the noise value given on the tyre label corresponds with the ranking according to measured sound levels during CPX measurements on ISO test tracks. The average value of SPLs at 80 km/h calculated for all test tracks were used for this comparison. The obtained results were presented in Table 18.

Table 18. *Tyre ranking comparison*

Manufacturer	Tyre label		ISO test track								Average of all test tracks	
			ISO1		ISO2		ISO3		ISO4			
	Noise level	Position in ranking	SPL [dB]	Position in ranking	SPL [dB]	Position in ranking	SPL [dB]	Position in ranking	SPL [dB]	Position in ranking	**SPL [dB]**	**Position in ranking**
Dębica	**66** dB	**1**	92.5	6	93.9	8			93.5	6	**93.3**	**7**
Yokohama	**67** dB	**2**	90.8	1	91.7	1	91.2	1	91.7	1	**91.4**	**1**
Kenda	**68** dB	**3**	91.4	4	92.4	3			91.9	2	**91.9**	**2**
Michelin	**69** dB	**4**	91.4	3	92.9	4	92.5	5	92.7	4	**92.4**	**3**
Vredestein	**70** dB	**5**	91.3	2	92.1	2	94.0	6	93.2	5	**92.7**	**6**
Bridgestone	**71** dB	**6**	91.6	5	92.9	5	91.6	2	93.8	7	**92.5**	**4**
Continental	**72** dB	**7**	93.4	8	93.4	7	92.5	4	94.5	8	**93.4**	**8**
Momo	**73** dB	**8**	95.3	9	95.6	9			95.6	9	**95.5**	**9**
Evergreen	**74** dB	**9**	92.6	7	93.2	6	91.8	3	92.7	3	**92.6**	**5**

One can easily observe that the tyre ranking based on CPX noise measurements is totally different from the one based on noise values given on tyre labels. Neither the quietest nor the loudest tyre according to its label corresponds to the noise levels measured for these tyres with the CPX method. The positions in the middle of the stake are also different. Differences appear also between particular ISO test tracks. The cause of this inconsistency will be analyzed in detail after analyzing all the results obtained also when tested in laboratory conditions (within WP4).

4.8 MEASUREMENT OF L_{EQ}-LEVELS

The purpose of the measurements described in this chapter was to obtain data for the noise modelling which will be performed later in WP5. The noise indicator which will finally be used for the modelling will be the equivalent sound level (L_{eq}). However, due to the specificity of L_{eq}, which is dependent on the duration of the acoustic phenomenon, it was decided that in this report the results will be presented by the exposure sound level SEL. In this case, the results obtained are not dependent on the time the test car passes through the measurement cross-section. They can also be directly compared with each other. Finally, on this basis and with the results of the CPB measurements, it will be easy to calculate the appropriate indices for noise modelling in terms of equivalent sound level, which will be used to assess the environmental noise impact of the tested tyres. The obtained results will be supplemented by tests, which will be performed on real road surfaces used in Poland and Norway.

The tests were performed on one of the test tracks (ISO2). The measurement cross-section is shown below in Figure 21. The tests were performed at the same time and meteorological conditions as the CPB measurements described in the previous part of the report. Therefore, their results are mostly comparable. However, attention should be paid to a different location of the measurement microphone, which better represents the environmental impact of traffic noise, while the CPB method focuses on tyre/road noise. The location of the measurement microphone together with the sound level meter in relation to a passing test car is shown in Figure 22.

Figure 21. *View of test section on ISO2*

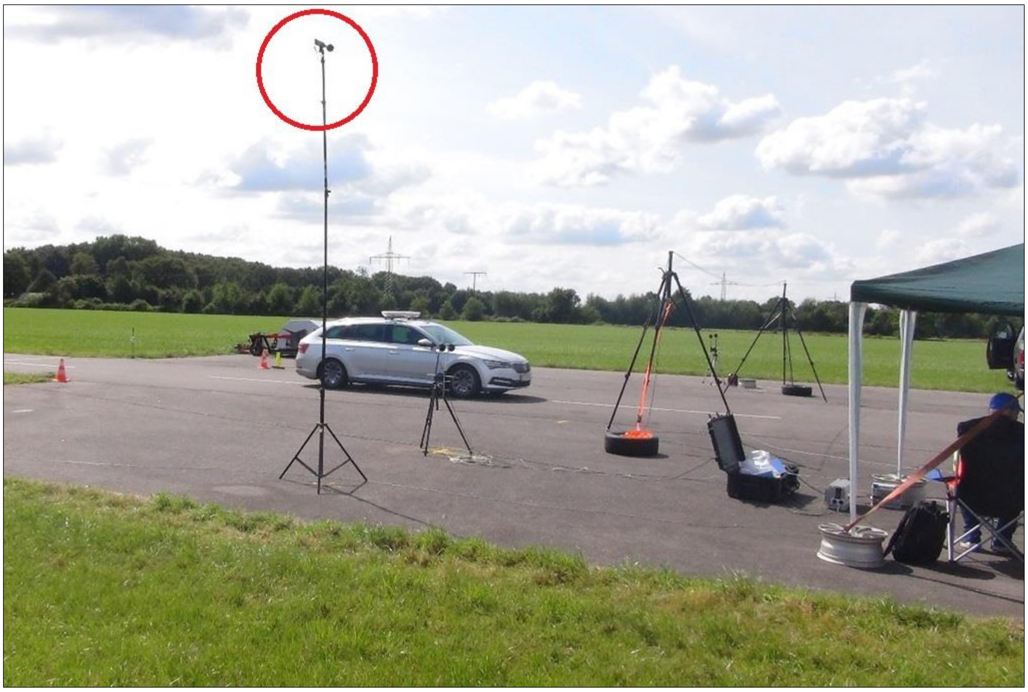

Figure 22. *View of the location of the measurement microphone with sound level meter*

The sound level meter with microphone was located 4 m above ground level and 10 m from the centerline of the test car's path. The ground around the test stand was hard and had sound reflective properties, as shown in the figure above. There were no other reflective surfaces in the immediate vicinity of the measurement microphone (apart from the road surface) that could affect the measurement results. The location of the microphone reflects the impact of road noise on the environment as it is located at a greater distance from the place where the tyre/road noise is generated and therefore the results also take into account other sound sources (e.g. engine sound, sound of power-train components, aerodynamic sounds at higher driving speeds). At the same height (4 m) environmental studies are also performed, including strategic noise maps (currently in preparation in the countries of the European Union).

The measurements were made with a class 1 sound level meter type SVAN 971. FAST time constant and type A weighting filter were used for the tests. In addition, all tests were performed using 1/3 octave frequency filters. Test results were stored in the instrument memory with a step equal to 1 s. The sound level meter was checked with a class 1 acoustic calibrator before and after the measurements. The view of the measuring instrument is shown below in Figure 23. In the case of exposure sound level measurements, the results were not corrected for temperature. Therefore, these results should not be directly compared with the results of the CPB measurements described in the previous chapter.

Figure 23. *View of the sound level meter SVAN-971*

The noise test results for all the types of tyres are shown below. Similarly, to the CPB measurements, these tests were performed at the load and inflation pressure specified in Reg.117 (load 530 kg, inflation pressure 200 kPa) and at the modified conditions (load 460 kg, inflation pressure 230 kPa) described in detail in Chapter 2.2. For better readability, the test results have been dispensed with in 1/3 octave frequencies and presented for the entire frequency range observed. First, Figure 24 – Figure 28 show the test results for the load and inflation pressure specified in Reg. 117.

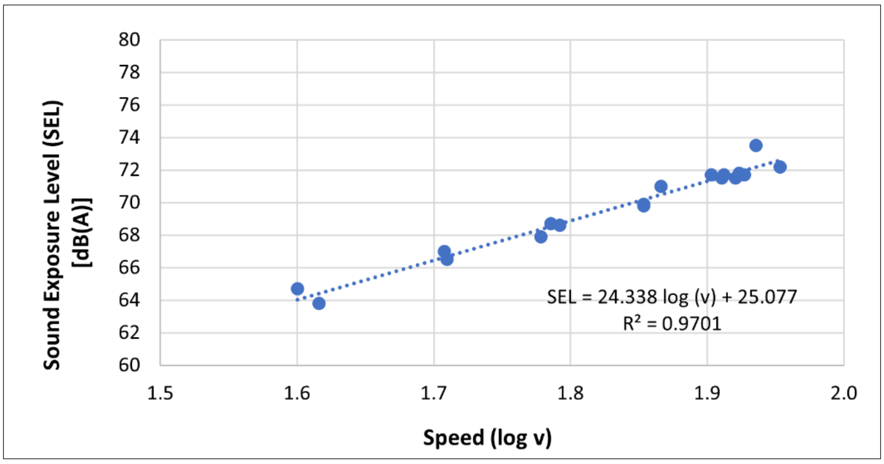

Figure 24. *Results of an exposure sound level measurement for Yokohama tyre under load of 530 kg and inflation pressure of 200 kPa*

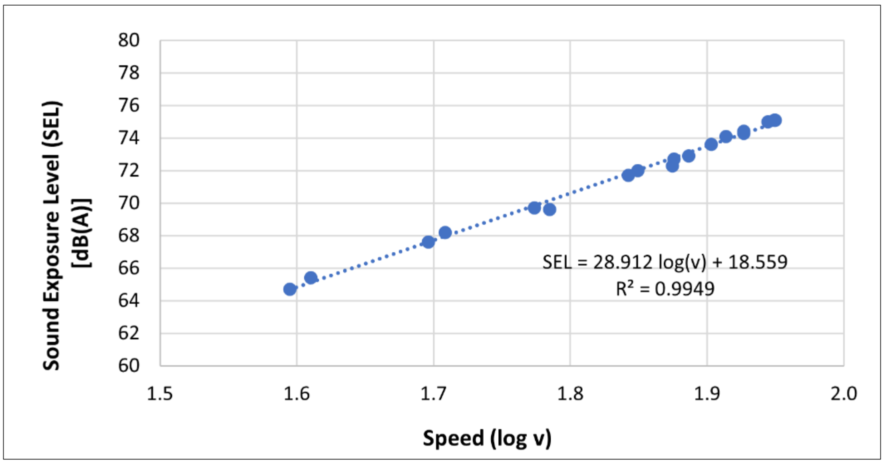

Figure 25. *Results of an exposure sound level measurement for Michelin tyre under load of 530 kg and inflation pressure of 200 kPa*

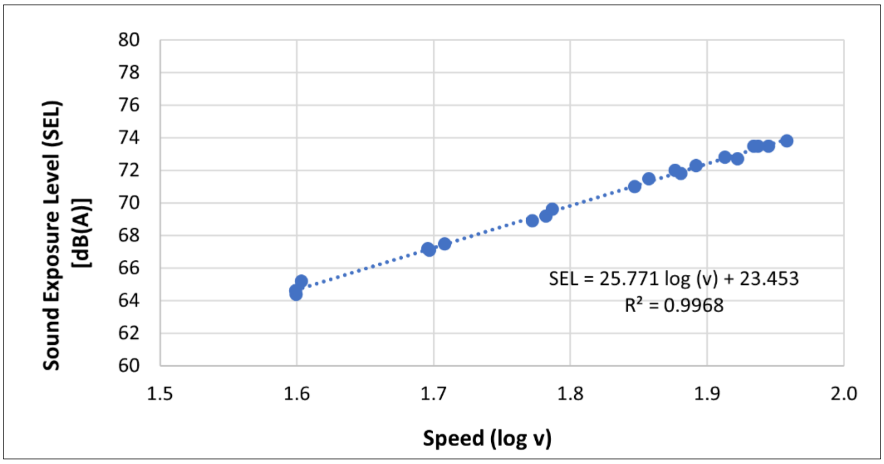

Figure 26. *Results of an exposure sound level measurement for Bridgestone tyre under load of 530 kg and inflation pressure of 200 kPa*

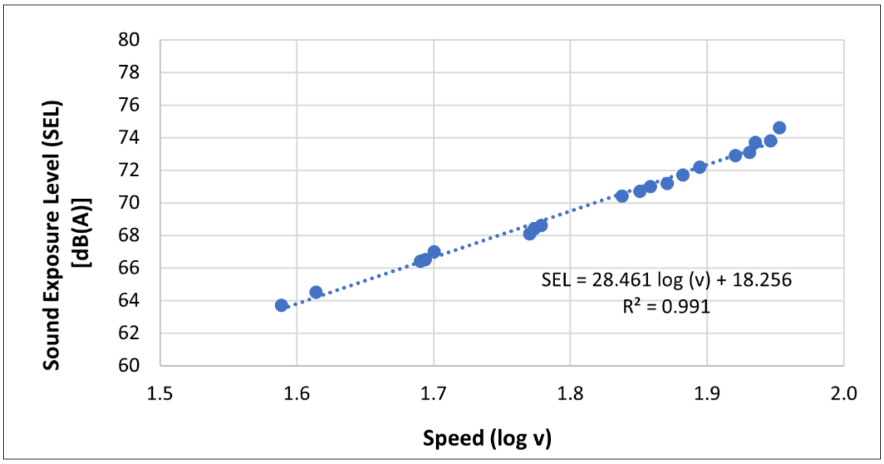

Figure 27. *Results of an exposure sound level measurement for Evergreen tyre under load of 530 kg and inflation pressure of 200 kPa*

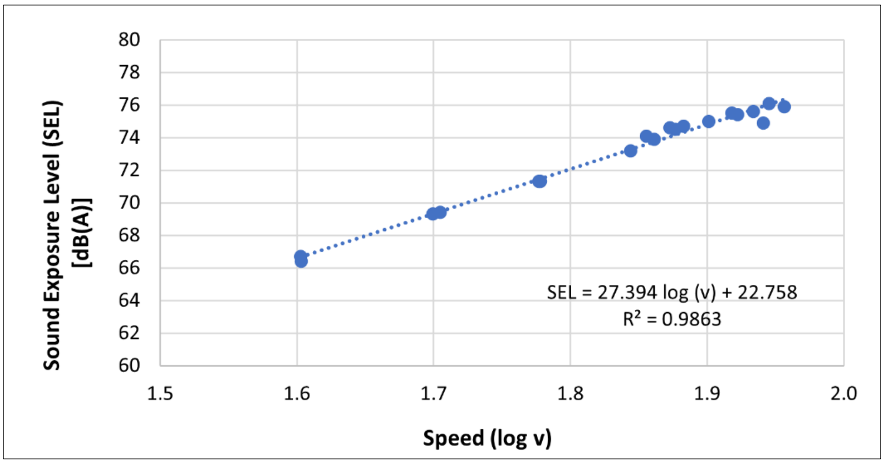

Figure 28. *Results of an exposure sound level measurement for SRTT tyre under load of 530 kg and inflation pressure of 200 kPa*

Based on the results of the SEL exposure sound level measurements, similar conclusions can be drawn as those obtained from the tests performed by the CPB method. The tyre with the lowest sound level is Yokohama. Both at low and high speeds at which the test car is driven, the exposure sound level is the lowest for this tyre. On the other hand, the loudest tyre is the SRTT. Compared to the other tyres, it produces by far the most noise. This can be seen in a better way in Figure 29, which shows the exposure sound levels for 50 km/h and 80 km/h obtained from linear regression analysis (as a function of the logarithm of speed).

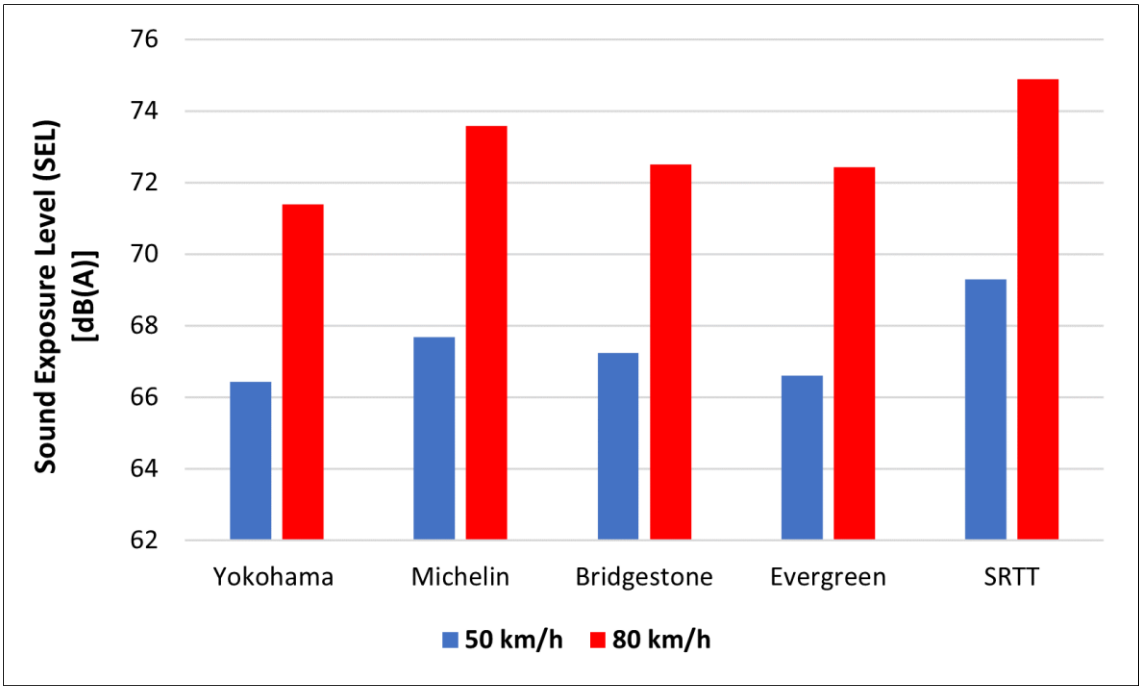

Figure 29. *Measurement results of the exposure sound level for the test tyres at 530 kg load and inflation pressure of 200 kPa obtained from linear regression analysis*

Based on the test results obtained, it will be possible to determine correction factors which will then be used for noise modelling in WP5. For this purpose, sound levels measured at 1/3 octave frequencies, which are not presented in this report, will additionally be used.

As mentioned earlier in ISO2, exposure sound level tests were also performed for load and inflation pressure modified with reference to Reg. 117. These results are shown below in Figure 30 – Figure 34 for each tyre tested and together for 50 km/h and 80 km/h calculated from the regression analysis (Figure 35).

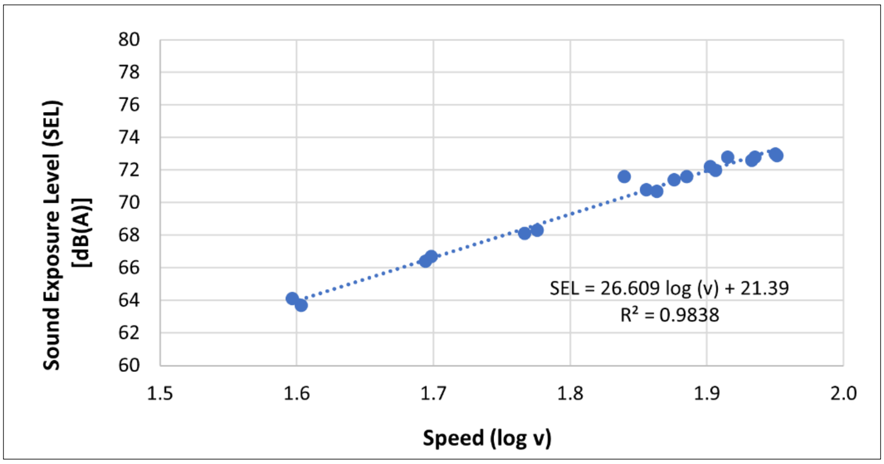

Figure 30. *Results of an exposure sound level measurement for Yokohama tyre under load of 460 kg and inflation pressure of 230 kPa*

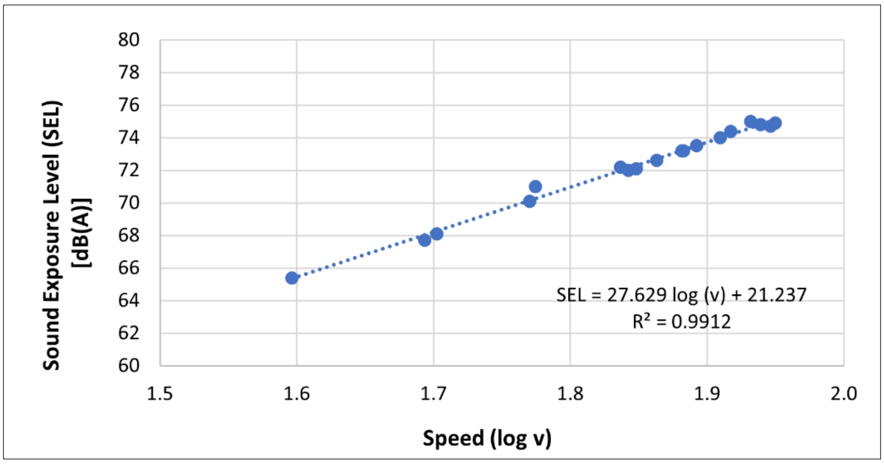

Figure 31. *Results of an exposure sound level measurement for Michelin tyre under load of 460 kg and inflation pressure of 230 kPa*

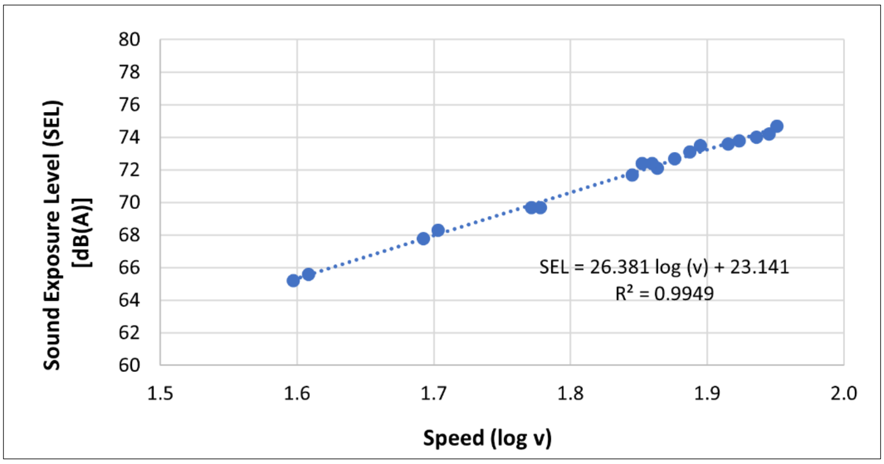

Figure 32. *Results of an exposure sound level measurement for Bridgestone tyre under load of 460 kg and inflation pressure of 230 kPa*

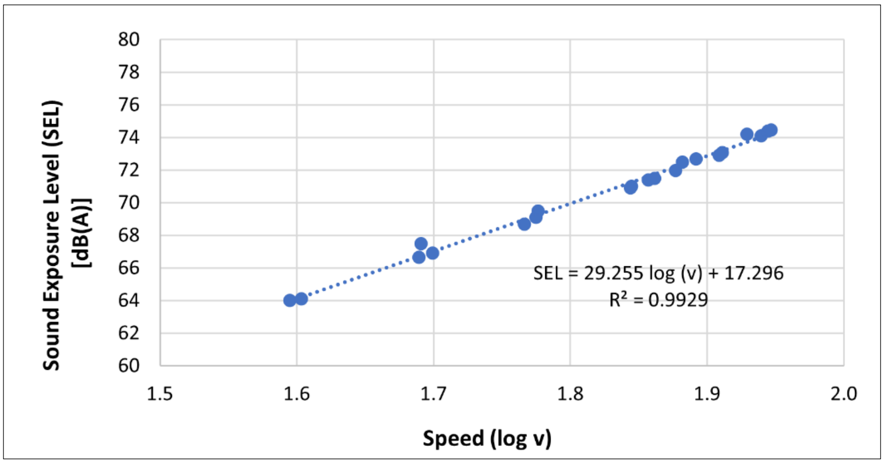

Figure 33. *Results of an exposure sound level measurement for Evergreen tyre under load of 460 kg and inflation pressure of 230 kPa*

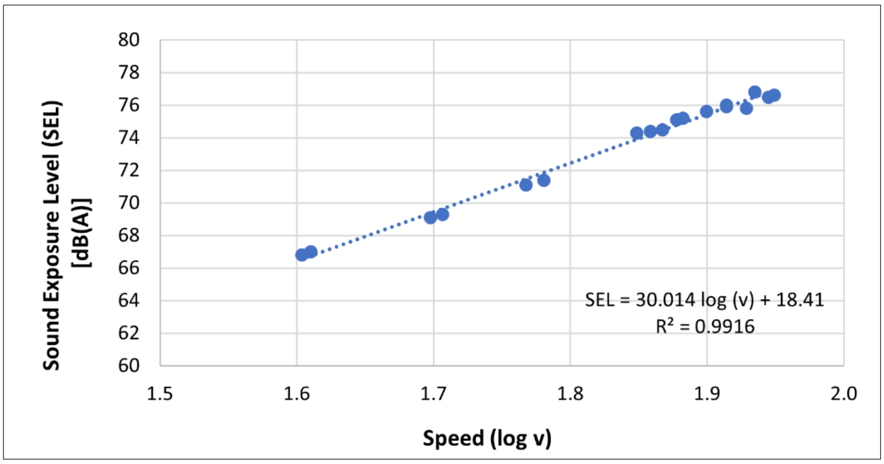

Figure 34. *Results of an exposure sound level measurement for SRTT tyre under load of 460 kg and inflation pressure of 230 kPa*

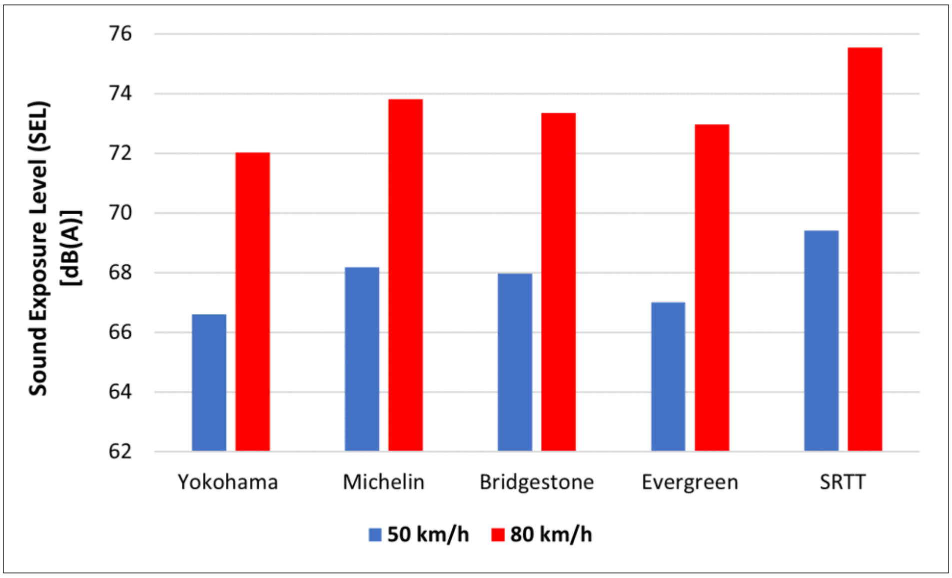

Figure 35. *Measurement results of the exposure sound level for the test tyres at 460 kg load and inflation pressure of 230 kPa obtained from linear regression analysis*

The results obtained for the modified conditions, from the point of view of environmental impact, do not differ significantly from those performed for the conditions strictly defined in Reg. 117. For the whole range of velocities tested, the results are similar to each other. This can be observed more clearly in Table 19 below, where the differences between the test results at different loads and inflation pressures are presented.

Table 19. *Comparison of results of measurement of exposure sound level at load and inflation pressure according to Reg. 117 and modified Reg. 117*

Tyre	**SEL** [dB(A)] (tyre load 530 kg, inflation pressure 200 kPa)		**SEL** [dB(A)] (tyre load 460 kg, inflation pressure 230 kPa)		**Difference** [dB(A)]	
	50 km/h	80 km/h	50 km/h	80 km/h	50 km/h	80 km/h
Yokohama	66.4	71.4	66.6	72.0	0.2	0.6
Michelin	67.7	73.6	68.2	73.8	0.5	0.2
Bridgestone	67.2	72.5	68.0	73.3	0.8	0.8
Evergreen	66.6	72.4	67.0	73.0	0.4	0.6
SRTT	69.3	74.9	69.4	75.5	0.1	0.6

The results shown in the table above indicate that, with a load of 460 kg and an inflation pressure of 230 kPa, the exposure sound level at 50 km/h and 80 km/h takes on greater values than for the conditions defined in Reg. 117. However, the differences between these results are less than 0.8 dB. From an environmental point of view, they are therefore not large. However, in order to formulate final conclusions, further studies need to be performed. These are planned in the final part of the project.

5 MEASUREMENT RESULTS ON CONVENTIONAL PAVEMENTS

5.1 CONTROLLED PASS-BY MEASUREMENTS

For all pavements, the results are shown for the Reg.117 and for the Light Test at two speeds: 50 and 80 km/h and for uncorrected, temperature corrected according to Reg.117, according to ISO and according to the proposal by ETRTO.

5.1.1 PAVEMENT MA11

Table 20and Table 21 the results from CPB measurements on the Ma11 pavement.

Table 20. *Measurement results on the Ma11 pavement for the Reg.117 test condition, using 3 different temperature correction procedures*

Tyre	Reg.117 50 km/h				Reg.117 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	67.4	67.6	67.0	67.7	74.4	74.6	74.1	74.7
Michelin	67.3	67.4	66.8	67.4	75.1	75.2	74.6	75.2
Bridgestone	68.0	68.5	67.9	68.3	74.8	75.3	74.7	75.1
Evergreen	67.3	67.6	67.0	67.7	74.7	75.0	74.4	75.0
SRTT	68.4	68.8	68.2	68.9	75.2	75.5	74.9	75.6

Table 21. *Measurement results on the Ma11 pavement for the Light test condition, using 3 different temperature correction procedures*

Tyre	Light test 50 km/h				Light test 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	66.6	67.1	66.4	67.2	74.1	74.6	73.9	74.6
Michelin	66.9	67.4	67.0	67.3	74.5	75.0	74.5	74.8
Bridgestone	67.6	68.3	67.5	68.1	74.9	75.5	74.7	75.2
Evergreen	66.8	67.2	66.6	67.3	74.7	75.1	74.5	75.2
SRTT	68.2	68.8	68.1	68.8	75.0	75.6	75.0	75.6

5.1.2 PAVEMENT SMA8

(Note that for Polish pavements, no road surface temperature was available)

Table 22 shows the results from CPB measurements on the SMA8 pavement. No measurements for the LT were performed at this location.

Table 22. *Measurement results on the SMA8 pavement for the Reg.117 test condition, using 3 different temperature correction procedures*

Tyre	Reg.117 50 km/h				Reg.117 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	68.2	68.6	68.0	68.7	74.7	75.0	75.5	75.1
Michelin	68.3	68.7	68.1	68.6	75.7	76.0	75.4	75.9
Bridgestone	69.1	69.5	68.9	69.0	76.0	76.4	75.8	76.4
Evergreen	68.3	68.6	68.1	68.7	75.2	75.6	75.1	75.7
SRTT	70.8	70.9	70.0	70.9	77.9	78.0	77.2	78.0

5.1.3 PAVEMENT SMA11

Table 23 and Table 24 show the results from CPB measurements on the SMA11 pavement.

Table 23. *Measurement results on the SMA11 pavement for the Reg.117 test condition, using 3 different temperature correction procedures*

Tyre	Reg.117 50 km/h				Reg.117 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	69.0	69.4	68.9	69.5	76.1	76.5	76.0	76.6
Michelin	68.8	69.2	68.6	69.1	76.6	77.0	76.4	76.9
Bridgestone	69.6	69.9	69.4	70.0	76.6	77.0	76.4	77.1
Evergreen	69.2	69.6	69.0	69.7	76.6	76.9	76.4	77.0
SRTT	70.8	71.2	70.6	71.2	77.8	78.3	77.8	78.4

Table 24. *Measurement results on the SMA11 pavement for the Light test condition, using 3 different temperature correction procedures*

Tyre	Light test 50 km/h				Light test 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	69.0	69.4	68.8	69.5	76.2	76.6	76.1	76.7
Michelin	68.9	69.3	68.7	69.1	76.5	76.9	76.3	76.8
Bridgestone	70.0	70.3	69.7	70.4	76.9	77.2	76.6	77.3
Evergreen	69.7	70.1	69.4	70.1	77.1	77.4	76.8	77.5
SRTT	70.5	70.9	70.4	71.0	78.0	78.4	77.8	78.4

5.1.4 PAVEMENT SMA16

Table 25 and Table 26 show the results from CPB measurements on the SMA11 pavement.

Table 25. *Measurement results on the SMA16 pavement for the Reg.117 test condition, using 3 different temperature correction procedures*

Tyre	Reg.117 50 km/h				Reg.117 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	69.8	70.3	70.0	70.4	77.2	77.7	77.4	77.8
Michelin	68.6	69.1	68.7	69.0	76.0	76.5	76.0	76.3
Bridgestone	68.8	69.3	69.1	69.1	76.0	76.4	76.2	76.3
Evergreen	69.9	70.4	70.0	70.5	77.2	77.8	77.3	77.8
SRTT	70.0	70.5	70.3	70.6	76.9	77.4	77.0	77.4

Table 26. *Measurement results on the SMA16 pavement for the Light test condition, using 3 different temperature correction procedures*

Tyre	Light test 50 km/h				Light test 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	70.1	70.7	70.2	70.8	77.7	78.3	77.8	78.3
Michelin	68.5	68.8	68.6	68.7	76.1	76.4	76.2	76.3
Bridgestone	68.9	69.4	69.0	69.2	76.3	76.8	76.4	76.6
Evergreen	70.2	70.8	70.3	70.8	77.7	78.3	77.8	78.3
SRTT	70.3	70.7	70.3	70.8	77.3	77.8	77.5	77.9

5.1.5 PAVEMENT EACC

Table 27 and Table 28 show the results from CPB measurements on the EACC pavement.

Table 27. *Measurement results on the EACC pavement for the Reg.117 test condition, using 3 different temperature correction procedures*

Tyre	Reg.117 50 km/h				Reg.117 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	69.1	69.5	68.9	69.5	76.4	76.7	76.1	76.8
Michelin	67.9	68.2	67.5	68.1	75.5	75.8	75.2	75.8
Bridgestone	68.8	69.1	68.4	69.2	76.0	76.3	75.6	76.4
Evergreen	69.2	69.5	68.9	69.6	76.7	77.0	76.4	77.1
SRTT	69.6	69.9	69.3	70.0	76.8	77.2	76.6	77.3

Table 28. *Measurement results on the EACC pavement for the Light test condition, using 3 different temperature correction procedures*

Tyre	Light test 50 km/h				Light test 80 km/h			
	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)	Non corr. dB(A)	Reg.117 dB(A)	ISO dB(A)	ETRTO dB(A)
Yokohama	69.4	69.6	68.8	69.6	76.7	76.8	76.1	76.9
Michelin	68.0	68.0	67.1	68.0	75.6	75.7	74.8	75.7
Bridgestone	68.8	68.8	67.9	68.8	76.2	76.1	75.2	76.1
Evergreen	69.6	69.4	68.6	69.5	77.2	77.1	76.2	77.1
SRTT	70.1	70.2	69.3	70.2	77.5	77.6	76.7	77.6

5.2 RANKING OF TYRES ON CONVENTIONAL PAVEMENTS

Figure 36 to Figure 40 show the ranking of the tyres for the five tested pavements at 50 and 80 km/h.

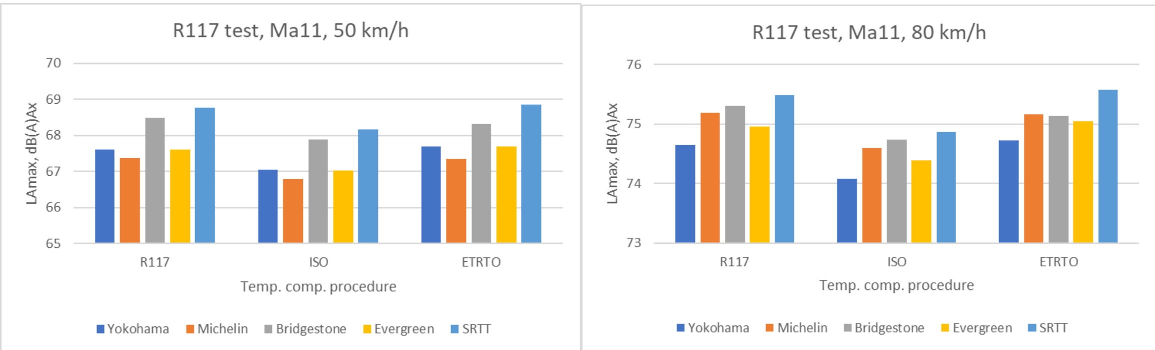

Figure 36. *Reg.117 test. Noise ranking of tyres on Ma11 with 3 different temperature compensation procedures applied. Speeds 50 and 80 km/h*

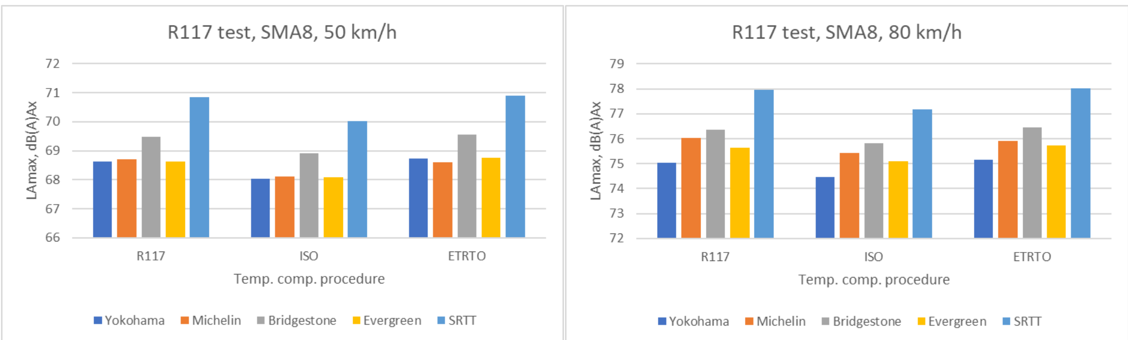

Figure 37. *Reg.117 test. Noise ranking of tyres on SMA8 with 3 different temperature compensation procedures applied. Speeds 50 and 80 km/h*

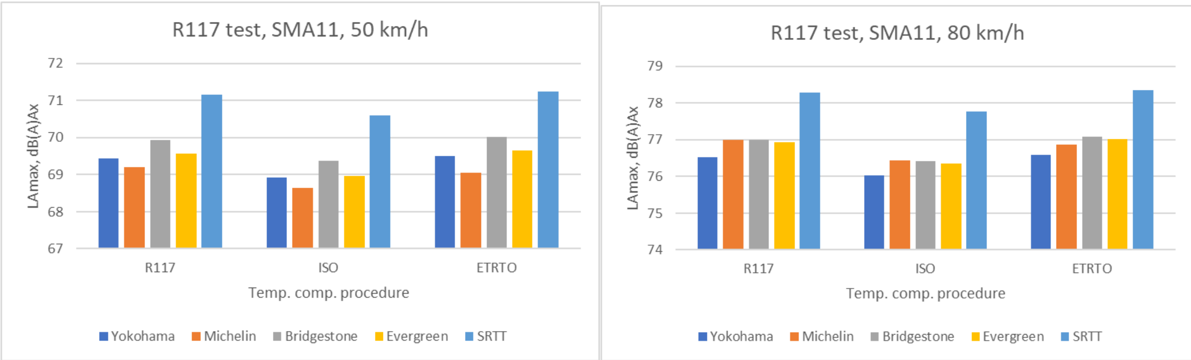

Figure 38. *Reg.117 test. Noise ranking of tyres on SMA11 with 3 different temperature compensation procedures applied. Speeds 50 and 80 km/h*

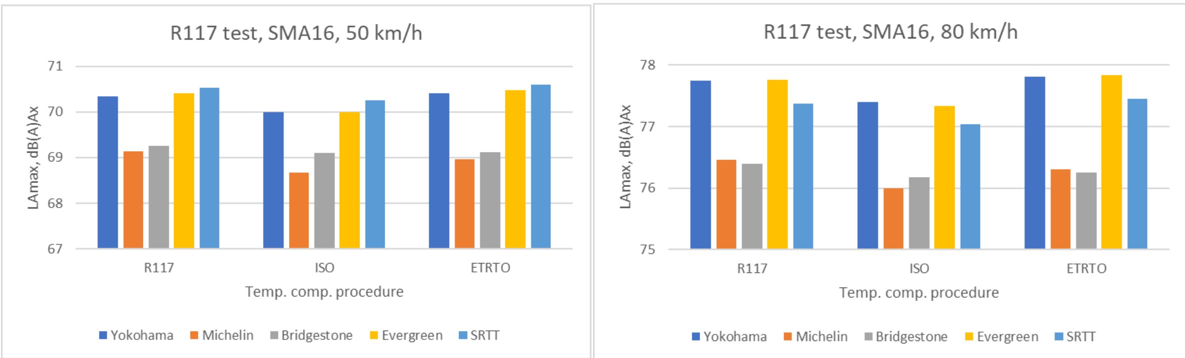

Figure 39. *Reg.117 test. Noise ranking of tyres on SMA16 with 3 different temperature compensation procedures applied. Speeds 50 and 80 km/h*

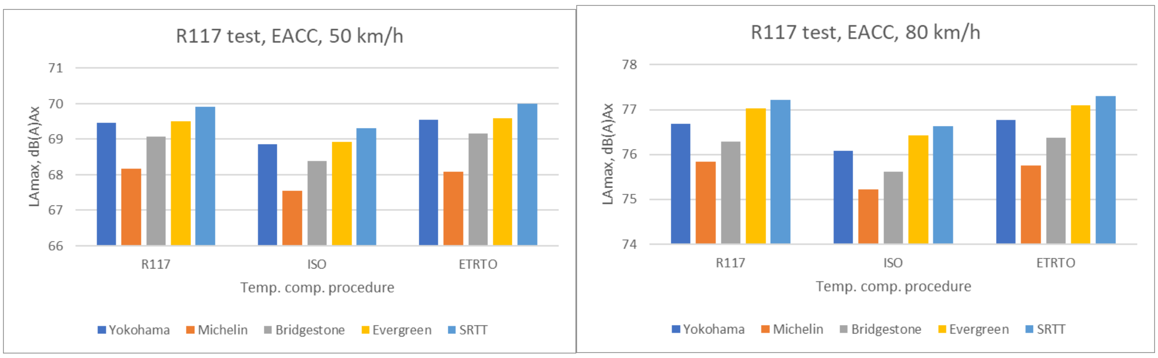

Figure 40. *Reg.117 test. Noise ranking of tyres on EACC with 3 different temperature compensation procedures applied. Speeds 50 and 80 km/h*

The results shown in Table 20 - Table 28 and Figure 36 - Figure 40 show the following:

- The ranking does not change significantly with the temperature compensation procedure applied.
- The ranking of the tyres on the SMA16 and the EACC pavement types is quite different than on the smooth pavements like the Ma11 and SMA8. The Yokohama tyre being one of the tyres with the highest levels on the SMA16, while it is the quietest on the Ma11. The SRTT tyre is normally assumed to be noisier than the typical C1 tyres, as is the case on all the measured ISO tracks (see Figure 19) and this is also the case on the Ma11. However, on the rough SMA16 pavement, this is no longer the case, as both the Yokohama and the Evergreen tyres are measured with higher noise levels.
- The so-called Light test does not shift the ranking of the tyres, as shown in Table 20 - Table 21. As for the tests on the ISO tracks (Table 17), the difference between the Reg.117 test and the Light test is always less than 0.5 dB.

5.2.1 COMPARISON WITH ISO VALUES AND EU NOISE LABEL VALUES

Figure 41 shows the measured noise levels on the 3 ISO tracks where we have a complete set of results, compared with the noise levels on the five conventional pavements. The average level on each of the pavements is also included.

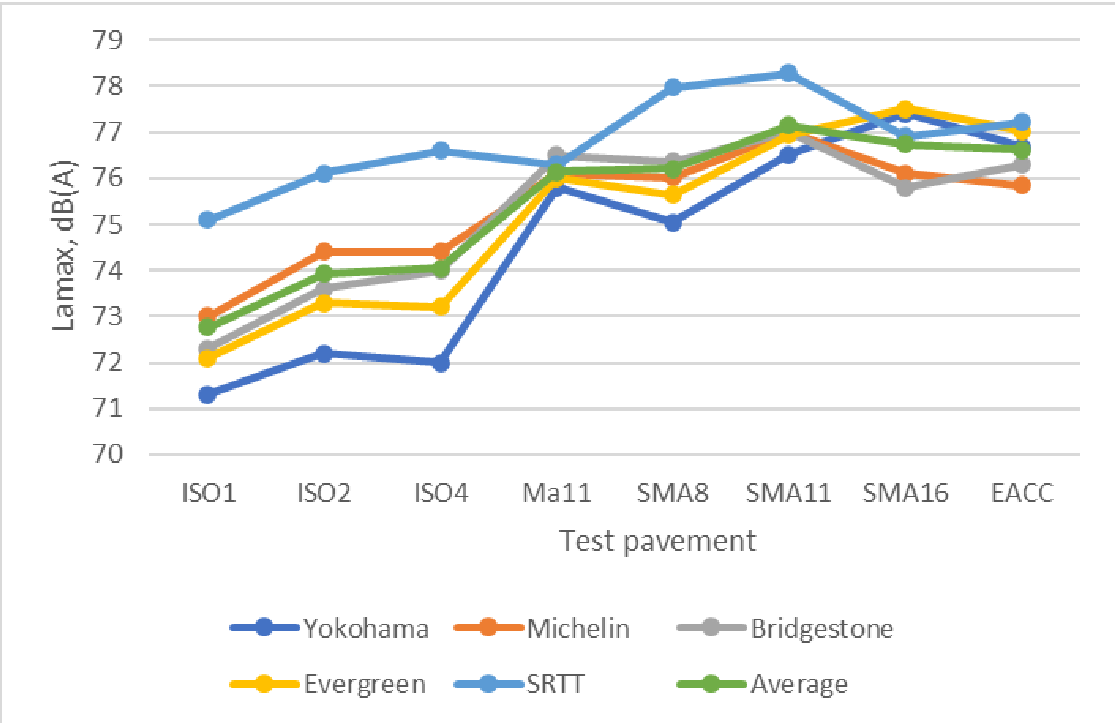

Figure 41. *Noise levels according to Reg.117 on 3 ISO tracks and the five conventional pavements for 5 C1 tyres, including SRTT tyre*

The figure above shows some important results:

- The ranking of the tyres does not shift on the ISO tracks.
- On all ISO tracks, the SRTT tyre is clearly the noisiest. However, this is not the case on some of the conventional pavements.
- The spread of noise levels between the measured tyres are in the range of 4 dB on the ISO tracks, while only 1 dB on the Ma11 and 1.4 dB on the SMA16.
- The small difference between the measured levels on the ISO tracks and the SMA16, as well as the differences between SMA8/SMA11 and SMA16, is most likely due to some major influence of the propagation of the sound from the source and the microphone at the SMA16 location. As seen in figure 7, there is a grass covered area between the driving lane and the pedestrian/bicycle area, where the microphone (1.2 m height) is positioned. This area provides attenuation of the sound. This is confirmed, both by the CPX results (reported in TR15-ELANORE-GUT-11 (2022)) and from the SEL measurements at 4 m height and 10 distance.

Figure 42 shows the ranking according to the EU label values and the ranking on the five conventional pavements.

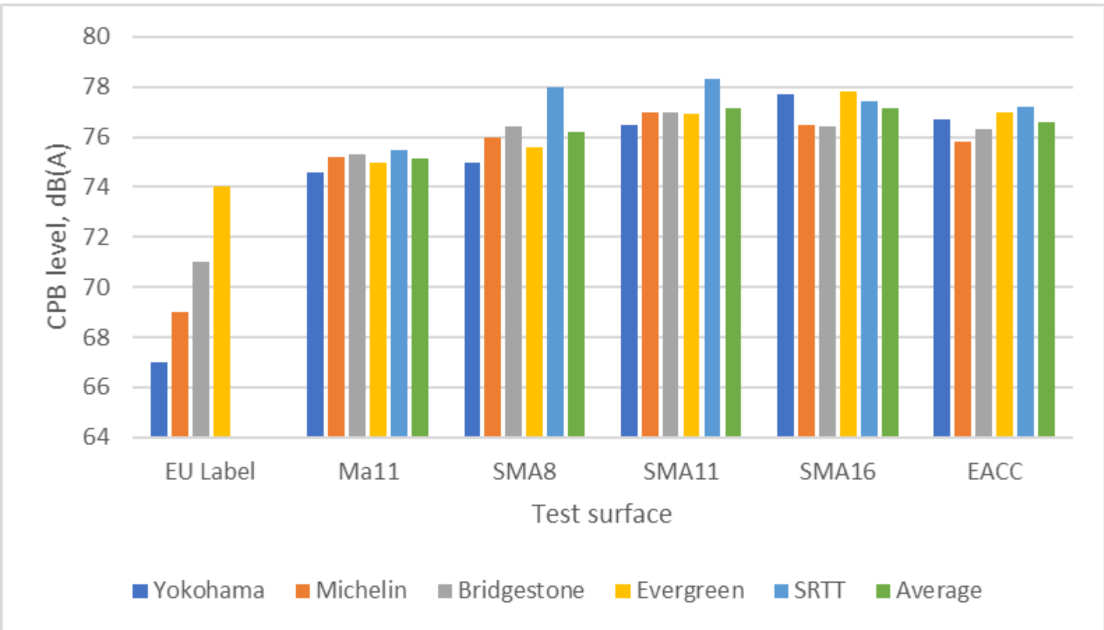

Figure 42. *Comparison of the EU label values and measured values on the five pavements*

From previous investigations [11, 12] it was expected that there was a poor correlation between label values from a smooth ISO track and the rough SMA16 pavement and the EACC, which we clearly see from Figure 42.

As shown in Table 11, the measurements on the 3 ISO tracks do not correspond to the label values given by the manufacturers. Therefore, it was important to see if the correlation between the actual measured levels on the ISO tracks and the levels on the five conventional pavements were better than with the labelled values. Figure 43 shows the measured levels on the average of ISO test tracks and the five pavements.

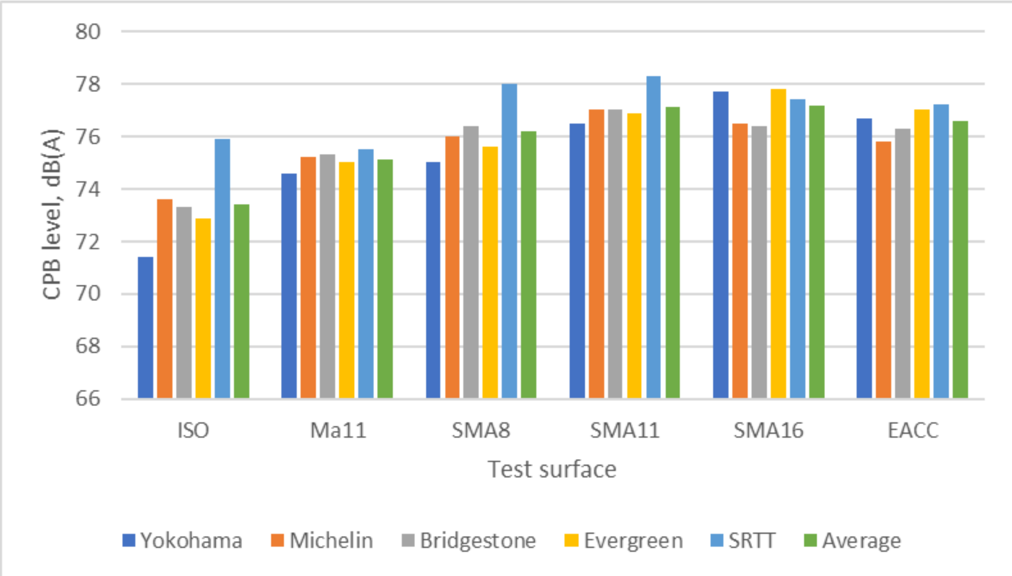

Figure 43. *Comparison of average measured values on ISO test tracks and measured values on the five pavements*

As seen in Figure 43, the smooth ISO surface gives a difference of more than 4 dB between the quietest and noisiest tyre. On the Ma11 surface, there is almost no difference (0.7 dB). This is somewhat unexpected, as this is also a smooth surface, which should discriminate more than shown here. It was quite windy during the measurements on this location (gusts up to 8-10 m/s), which may have influenced the results. On both ISO surfaces and on the Ma11, CPX measurements have been made, using the same tyres as for CPB. These measurements should not be influenced by any wind conditions, and the analysis of CPX results in WP4 should give an indication if the CPB results were influenced by the environmental conditions.

To evaluate the relationship between noise levels on ISO test tracks and the tested pavements, a linear regression analysis has been made. For this analysis, the average level on the ISO tracks results is used. It shows the correlation between the levels (R^2) and the potential reduction of levels based on the slope of the curve. If this slope is equal to 1.0, it means that a reduction of 1 dB on the ISO track gives a reduction of 1.0 dB on the pavement. The regression analysis for the five pavements is shown below.

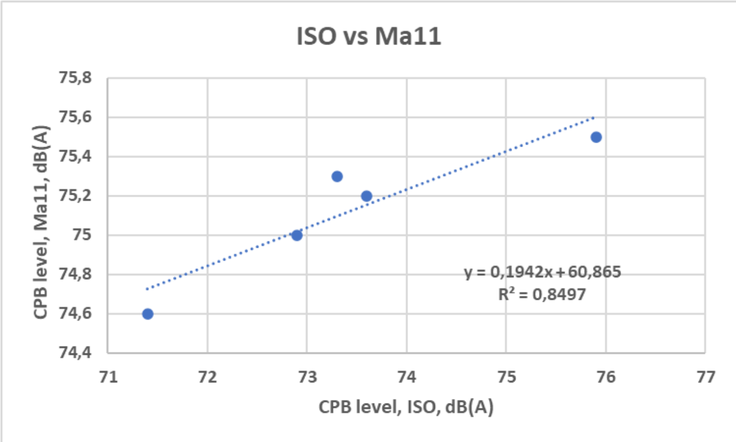

Figure 44. *Linear regression analysis between measured levels on ISO test tracks and Ma11*

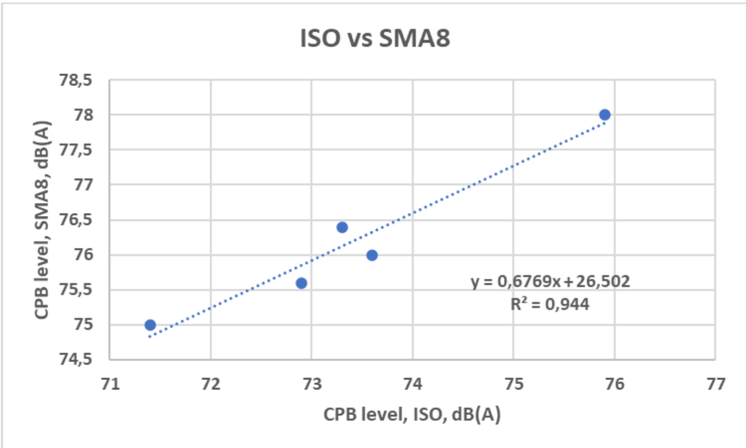

Figure 45. *Linear regression analysis between measured levels on ISO test tracks and SMA8*

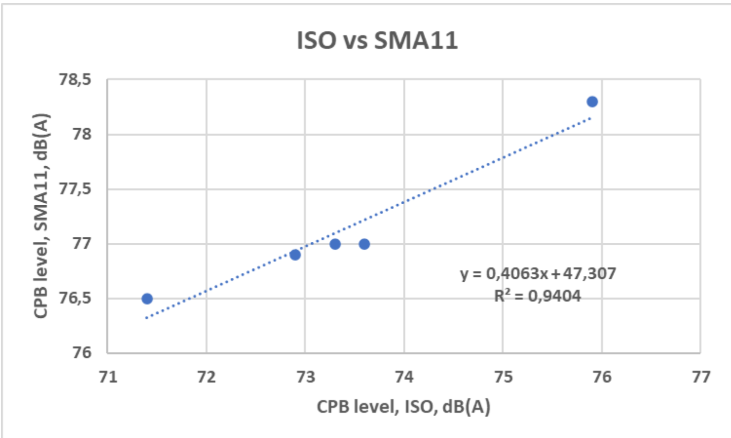

Figure 46. *Linear regression analysis between measured levels on ISO test tracks and SMA11*

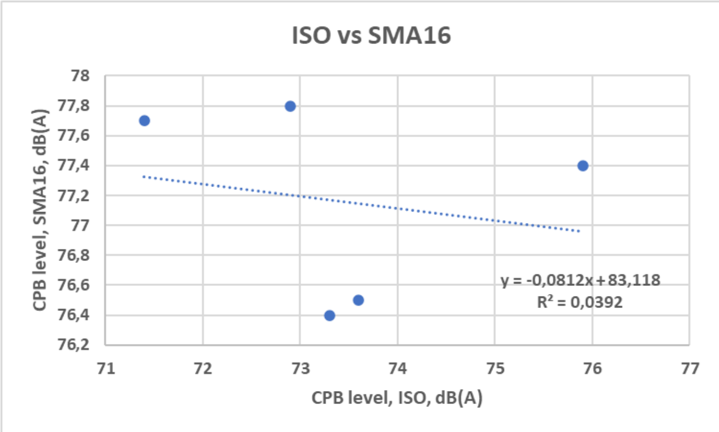

Figure 47. *Linear regression analysis between measured levels on ISO test tracks and SMA16*

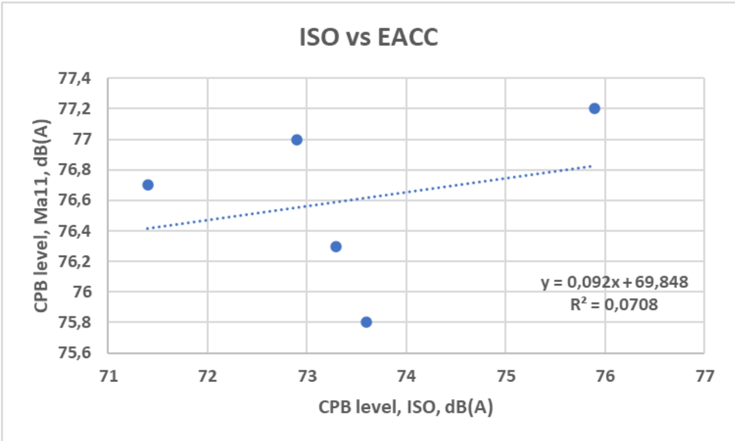

Figure 48. *Linear regression analysis between measured levels on ISO test tracks and EACC*

It should be noted that a small sample of only 5 tyres gives the analysis limited validation of the relationship between the levels. However, it gives an indication, and it confirms that there is a better correlation between measured levels on the ISO test tracks and on pavements with smooth texture and smaller chipping sizes. The ISO surface is in principle a dense asphalt surface with 8 mm maximum chipping sizes. As figure 45 shows, the highest correlation was found between ISO4 and the SMA8 pavement, with a regression coefficient R^2 = 0.94.

Even if the difference in noise levels is rather small on the Ma11 surface, the correlation with measured ISO levels is rather high with a regression coefficient R^2 = 0.85.. If the tyres had been labelled according to the noise levels found on these ISO tracks, there is a potential for using low noise tyres on the kind of smooth surfaces as Ma11 and SMA8.

As Figure 47 and Figure 48 show, there is no correlation at all between the measured noise levels on the ISO tracks and on the rougher SMA16 and EACC pavements, which is in line with previous investigations [11, 12].

5.3 MEASUREMENT OF LEQ-LEVELS

Similarly to the measurements on the ISO2 test track, the aim of the measurements is to obtain data for the noise modelling to be done in WP5. The parameter used to present the results of the measurements is the exposure sound level SEL due to the independence of the noise level from the time the car passes through the measurement cross-section. Measurements were taken in the vicinity of two road sections located in Skjeberg and Sørum, Norway. The characteristics of the road surfaces used on these road sections are described in detail in Chapter 2.5.2 of the report.

The location of the measurement microphone is shown in Figure 49 and Figure 50 below. The sound level meter with microphone was placed 4 m above ground level and 10 m from the centerline of the test car track, similar to the measurements on the ISO2 test track. The ground around the test stand was soft and had sound-absorbing properties. There were no other reflective surfaces in the direct vicinity of the measurement microphone (except the road surface) that could affect the measurement results.

Figure 49. *Location of the measurement microphone in the road surroundings in Skjeberg (Ma11 surface)*

Figure 50. *Location of the measurement microphone in the road surroundings in Sørum (SMA16 surface)*

The measurements were made at the same time and under the same meteorological conditions as the CPB measurements described in Chapter 5.1 of the report. Measurements were made with a Class 1 sound level meter of type SVAN 971. The FAST time constant and type A weighting filter were used for testing. In addition, all tests were made with 1/3 octave frequency filters. Test results were stored in the device's memory with a step equal to 1 s. The sound level meter was checked with a class 1 acoustic calibrator before and after the measurements. For the exposure sound level measurements, the results were not corrected for temperature. The results of the measurements are presented separately for the two road sections in Chapter 5.3.1 and 5.3.2 below.

5.3.1 PAVEMENT MA11

The results of the noise measurements for all tyre types are shown below. As with the CPB measurements and on the ISO2 track, these tests were done with load and air pressure under conditions modified to Reg. 117 (load 460 kg, air pressure 230 kPa) as described in detail in Chapter 2.2. For better clarity, the test results in 1/3 octave frequencies were omitted and are presented for the entire observed frequency range. Figure 51 - Figure 55 show the test results for all five tyres separately and Figure 56 presents a summary of the results for all tyres obtained from the regression analysis.

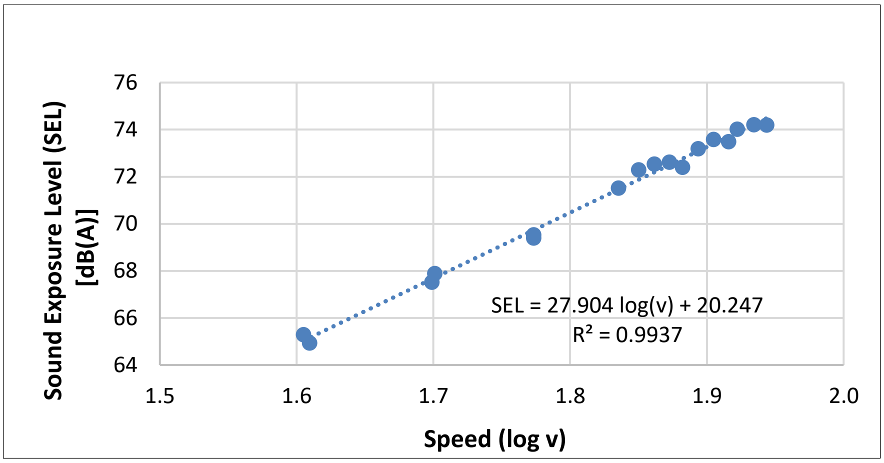

Figure 51. *Results of an exposure sound level measurement for Yokohama tyre under load of 460 kg and inflation pressure of 230 kPa*

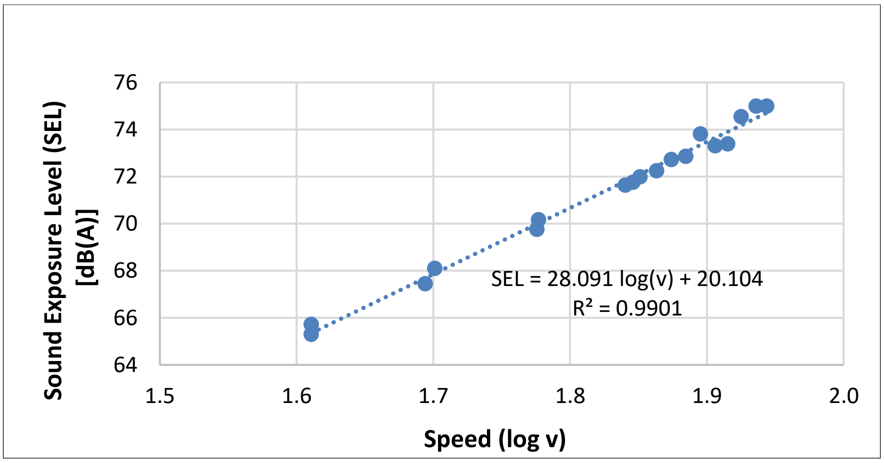

Figure 52. *Results of an exposure sound level measurement for Michelin tyre under load of 460 kg and inflation pressure of 230 kPa*

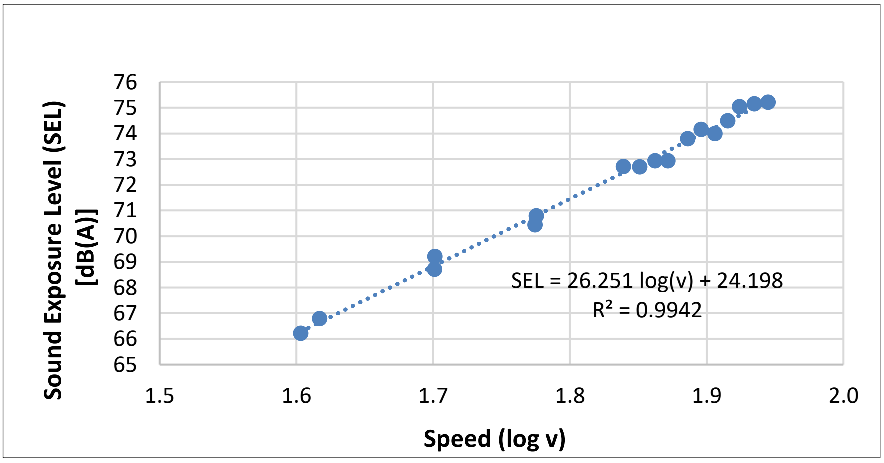

Figure 53. *Results of an exposure sound level measurement for Bridgestone tyre under load of 460 kg and inflation pressure of 230 kPa*

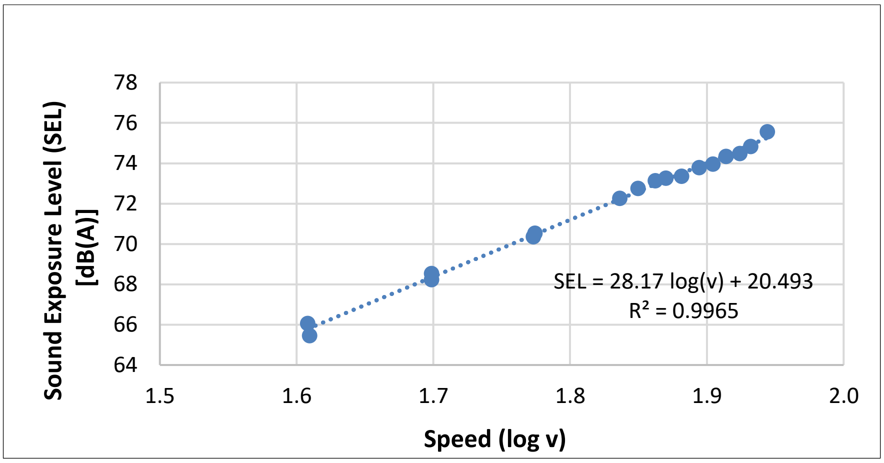

Figure 54. *Results of an exposure sound level measurement for Evergreen tyre under load of 460 kg and inflation pressure of 230 kPa*

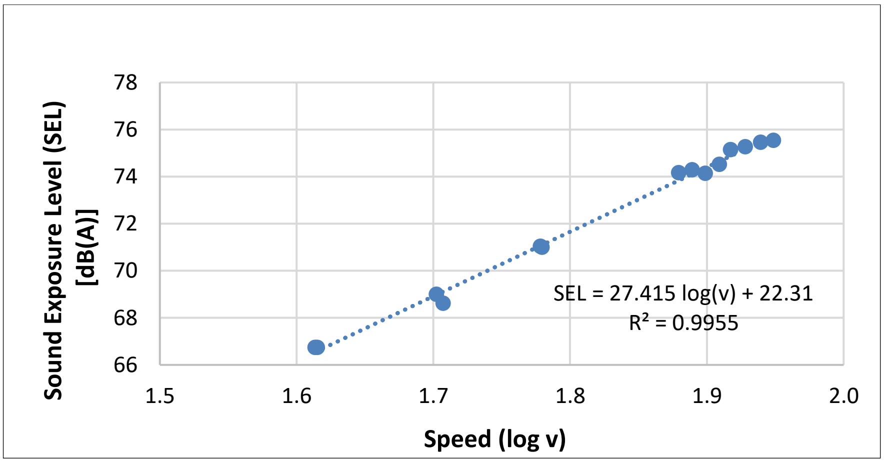

Figure 55. *Results of an exposure sound level measurement for SRTT tyre under load of 460 kg and inflation pressure of 230 kPa*

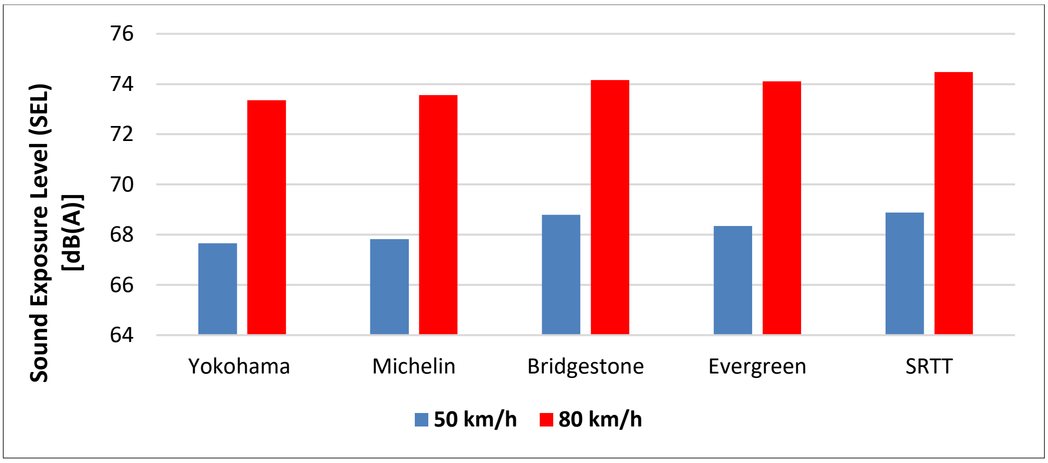

Figure 56. *Measurement results of the exposure sound level for the test tyres at 460 kg load and inflation pressure of 230 kPa obtained from linear regression analysis*

The data shown in the graph above indicates that, as on the ISO2 test track, the Yokohama tyre had the lowest noise level. In contrast, the SRTT tyre was the noisiest, which also agreed with the results obtained from the ISO2 test track. It should be noted that in the Ma11 road surroundings, the Michelin tyre had a fairly low noise level. Only the Yokohama tyre had lower noise level. In contrast, it was almost the loudest when measured on the ISO2 track. Only the SRTT tyre had a higher sound level.

5.3.2 PAVEMENT SMA16

Similarly, as for the Ma11 pavement, the noise results were tested under load and air pressure conditions modified to Reg. 117 (load 460 kg, air pressure 230 kPa). It should be noted that there was quite a lot of vehicle traffic on the tested road section, which disturbed the measurements to a small extent. It was not always possible for the entire acoustic event involving the pass-by of a test car to be undisturbed by the pass of another car. This did not affect the maximum sound level measured by the CPB method, but in the case of the SEL level, it may have slightly disturbed the measurement results.

Figure 57 - Figure 61 show the test results for all five tyres separately, and Figure 62 shows a summary of the results for all tyres obtained from the regression analysis.

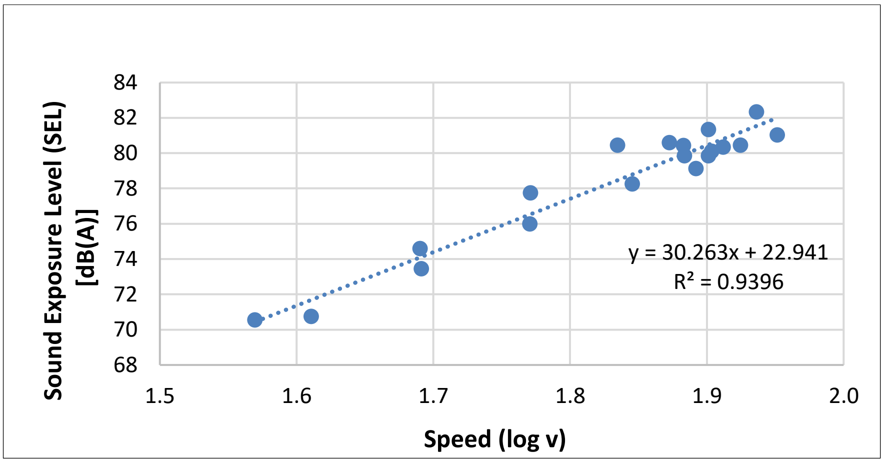

Figure 57. *Results of an exposure sound level measurement for Yokohama tyre under load of 460 kg and inflation pressure of 230 kPa*

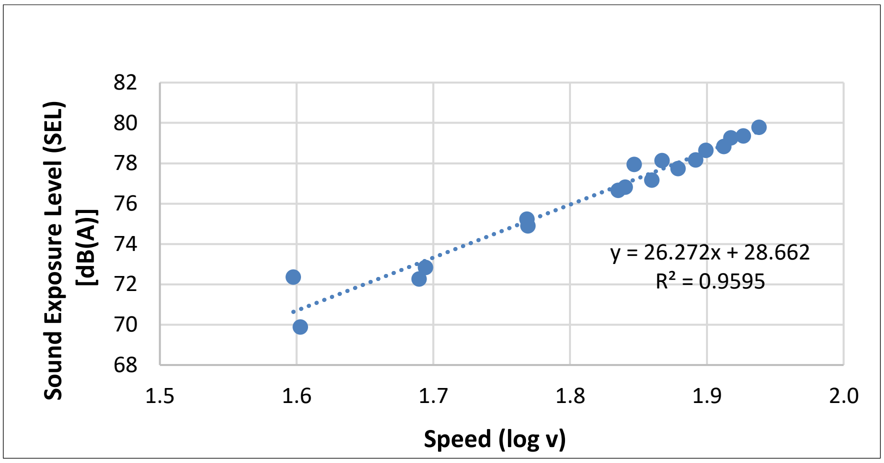

Figure 58. *Results of an exposure sound level measurement for Michelin tyre under load of 460 kg and inflation pressure of 230 kPa*

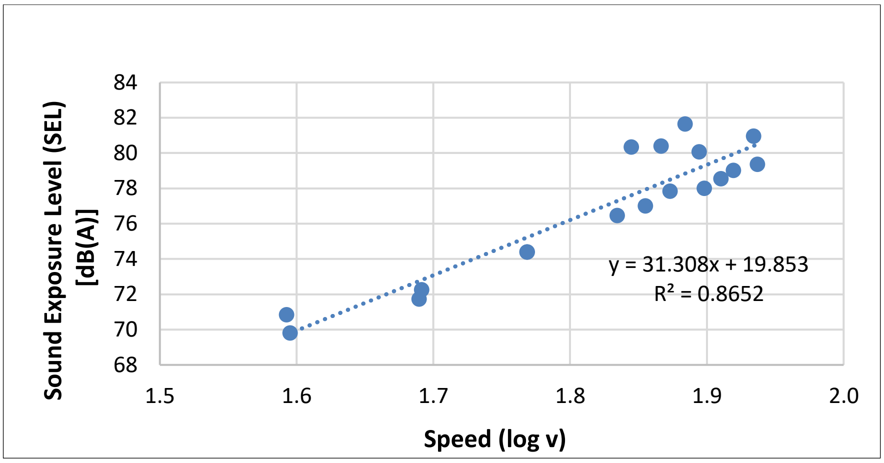

Figure 59. *Results of an exposure sound level measurement for Bridgestone tyre under load of 460 kg and inflation pressure of 230 kPa*

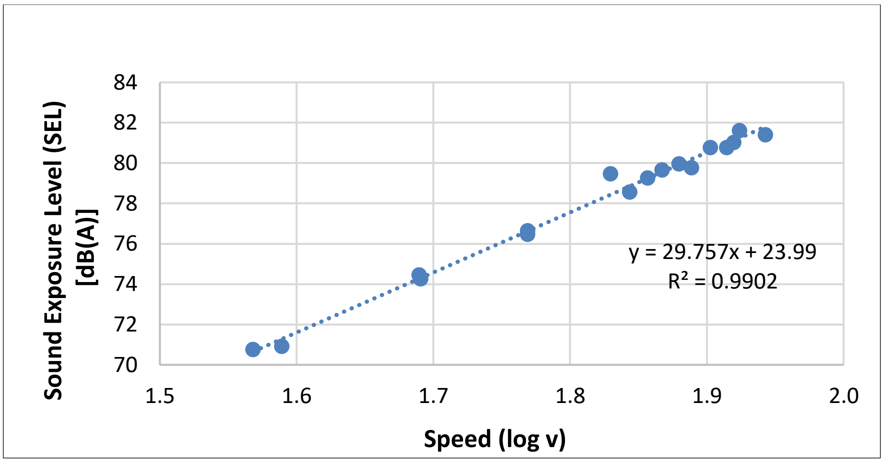

Figure 60. *Results of an exposure sound level measurement for Evergreen tyre under load of 460 kg and inflation pressure of 230 kPa*

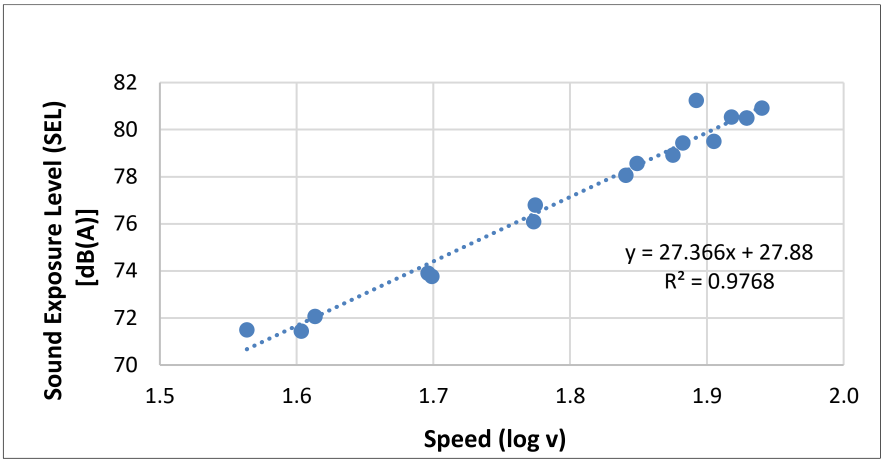

Figure 61. *Results of an exposure sound level measurement for SRTT tyre under load of 460 kg and inflation pressure of 230 kPa*

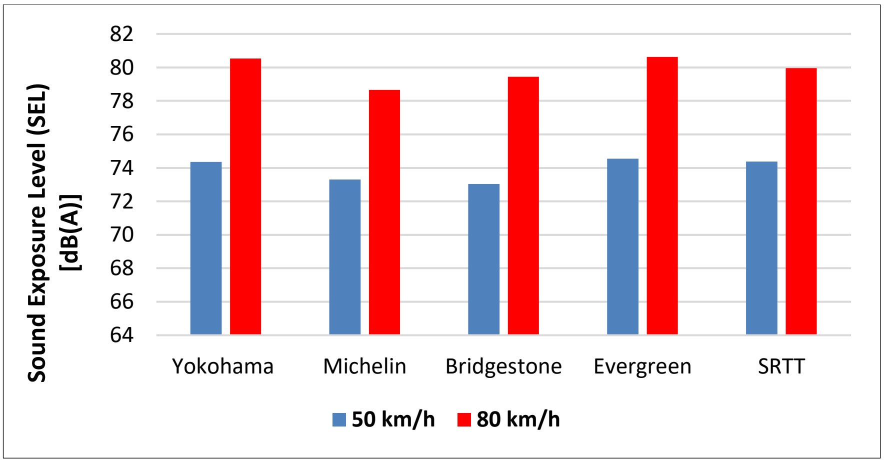

Figure 62. *Measurement results of the exposure sound level for the test tyres at 460 kg load and inflation pressure of 230 kPa obtained from linear regression analysis*

The measurement results for SMA16 differ slightly from those obtained for Ma11 and on the ISO2 test track. First of all, it should be noted that the noise level is higher for all tyres compared to the other road surfaces. The ranking of the tyres is also different. In this case, Bridgestone tyres appeared to be the quietest at 50 km/h and Michelin at 80 km/h. The noisiest tyre was Evergreen, which was almost the quietest on the ISO2 test track. In this case, the noise level generated by the SRTT tyre was no longer the highest. This tyre showed to be quieter than Yokohama and Evergreen.

All the results obtained, together with a set of CPB measurement data, will be used to make analyses as part of Work Package WP5. This part of the project will determine the impact of the modified tyre noise measurement method on environmental noise in road surroundings.

6 CONCLUSIONS

Controlled pass-by (CPB) and CPX measurements have been made on 4 ISO tracks in Europe. Due to some adverse weather situations, a full test program was not achieved on all ISO tracks. In addition to the ISO tracks, the same tyres have been measured on 2 trafficked roads in Norway and 3 roads in Poland.

A total of 5 passenger car tyres (C1) were measured according to UNECE Regulation 117 and the measured noise level of 4 of the tyres has been compared with the labelled values given by the tyre manufacturer. The ranking of the tyres on the measured ISO tracks does not correspond to the label ranking. This is not unexpected, as there are several important uncertainties related to both the R117 test procedure and the labelling procedure itself. The main uncertainties are:

- Track-to-track variation (found in some cases to be in the range of 4-5 dB)
- Variability within a tyre line (the tyre chosen for labelling purposes is normally the tyre assumed to have the highest noise level of a tyre line [13])
- Influence of environmental conditions (temperature, etc.)
- Test vehicle design (linked to wheel arch design, body height, etc.)

The two test conditions, R117 and LT did not influence the noise ranking of the tyres.

A comparison between the measured levels on the ISO tracks shows better correlation between the two smooth textured pavements Ma11 and SMA8. For the rougher pavement types (SMA16 and EACC) there is no correlation between the ranking of the tyres on the ISO track and these kinds of surfaces.

A total of 11 tyres (including the tyres for CPB) were also tested on the four ISO tracks, using the CPX method, with both test conditions concerning tyre load and tyre inflation pressure (R117 condition and LT condition). The GUT trailer was used for these measurements.

There was found no correlation between the ranking according to the CPX test and the ranking according to the label values on the ISO tracks.

General observations from the performed measurements are:

- The labelled values based on the tyre manufacturer do not correspond to the measured values from tests performed within this project according to Reg. 117 procedure on selected ISO tracks. However, for one of the tyres, there was only 1 dB difference (see Table 11).
- Based on measured noise levels on the ISO tracks, the ranking of the tyres fits better with the smooth textured pavements, like Ma11 and SMA8. However, the SMA11 also gives reasonable relationship to the ISO tracks.

In Work Package 4 of the project, all tyres have been measured on trafficked roads in Norway and Poland using the CPX method, and the results from these measurements will be compared to the CPB results. Based on these findings, an improved test method will be proposed including a "calibration" procedure to reduce the influence of the test track.

REFERENCES

[1] Berge T., Mioduszewski P., Bohatkiewicz J., Hałucha M.: *Technical Report on Controlled Pass-by and CPX Noise Measurements on ISO Tracks – Preliminary Results.* ELANORE Technical Report TR04-ELANORE-SINTEF-02 (2021)

[2] UN/ECE, 2011. *Provisions concerning the approval of tyres with regard to rolling sound emissions and to adhesion on wet surfaces and/or to rolling resistance.* Regulation No. 117 of the Economic Commission for Europe of the United Nations (UN/ECE), Geneva, Switzerland, (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A42011X1123%2803%29).

[3] International Organization for Standardization (ISO): *Acoustics – Method for measuring the influence of road surfaces on traffic noise – Part 2: The close proximity method*, ISO 11819-2:2017, Geneva, Switzerland, 2017

[4] International Organization for Standardization (ISO): *Acoustics – Specification of test track for measuring sound levels emitted by road vehicles and their tyres.* ISO 10844: 2021, Geneva, Switzerland, 2021

[5] VDA (2019): TFMU-01-03 (VDA) 2019-05-20-VDA-Final report RoRoTe Europe-20161103_EN_EXCERPT.pdf (https://wiki.unece.org/display/trans/TF+MU+-+1st+session%2C+Belgium+May+2019)

[6] International Organization for Standardization (ISO): *Acoustics - Temperature influence on tyre/road noise measurement - Part 2: Correction for temperature when testing with pass-by methods.* ISO/DTS 13471-2:2021, Geneva, Switzerland, 2021

[7] ETRTO: *ETRTO proposal for R117 C1 noise temperature correction update*, IWGMU 21-07. (https://wiki.unece.org/display/trans/IWG+MU+-21st+session%2C++Paris%2C+November+2022)

[8] Berge T., Mioduszewski P.: *Technical Report on test conditions for CPB and CPX measurements.* ELANORE Technical Report TR11-ELANORE-SINTEF-03 (2022)

[9] Bühlmann, E. et al.: *STEER Final Report*, 2022-01-15 (https://www.cedr.eu/docs/view/6373a6fec0dc7-en)

[10] International Organization for Standardization (ISO): *Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 3: Reference tyres,* ISO/TS 11819-3:2017, Geneva, Switzerland, 2017

[11] Kragh, et al.: *NordTyre – Tyre labelling and Nordic traffic noise – Analysis of data on passenger car tyres*. Report No.2018-1 NordFOU, 30 Nov.2014, revised June 2015.

[12] T. Berge, P. Mioduszewski, J. Ejsmont (2016)**:** *Final Report on Noise Measurements.* LEO-TUG-WP3-D002-2016-2-28.

[13] U. Sandberg, P. Mioduszewski**:** *The EU Tyre Noise Label: The problem with measuring the noise level of only a few of all tyre variants.* Proceedings of InterNoise 2022 Conference, Glasgow, UK, 2022.