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STEER

STEER
Strengthening the Effect of quieter tyres on European Roads

Report of the a priori uncertainty analysis of the tyre labelling procedure

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STEER: Strengthening the Effect of quieter tyres on European Roads

Report of the a priori uncertainty analysis of the tyre labelling procedure

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Author(s) of this deliverable: **Luc Goubert**

Main author/person responsible: Luc Goubert

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1 Introduction

An important part of WP2 of the STEER project is to assess the uncertainty budgets of the current labelling system as a basis for allocation of resources in STEER. The aspects of the current labelling system with the highest uncertainty contributions will also be the ones, which are the most important priorities to address in this project. Hence, (in arrangement with the PEB) the allocation of resources to WPs and Tasks may be changed according to the results of the uncertainty assessment in WP 2. At the end of the project, the uncertainty analysis is repeated in order to see how much the recommendations of this project will improve the labelling system, if implemented.

In the table in Annex I, the uncertainty budgets of the label measurement procedure, based on the measurement procedure outlined in [OJEU-2016], are evaluated following the concept of [ISO-2008]. This is based on the existing data for the tyre label. These uncertainty contributions can in certain cases be budgeted precisely, but in other cases one cannot do better than a rough estimate based on currently available expert knowledge.

The outcome is, nevertheless, a state-of-the-art uncertainty analysis of the procedure, clearly illustrating why the label in its present form is not optimal. It is demonstrated where the major challenges lie to come to a label with an acceptable reproducibility. The exercise will – as aforesaid – be repeated after the implementation of the proposals of this project. The allocation of resources will logically be made in order to address the highest uncertainty contributions.

2 Uncertainty analysis

2.1 Grouping of uncertainties

The basic document is the description of the method for the determination of the tyre noise label in [OJEU, 2016]. The procedure is schematically shown in Figure 1.

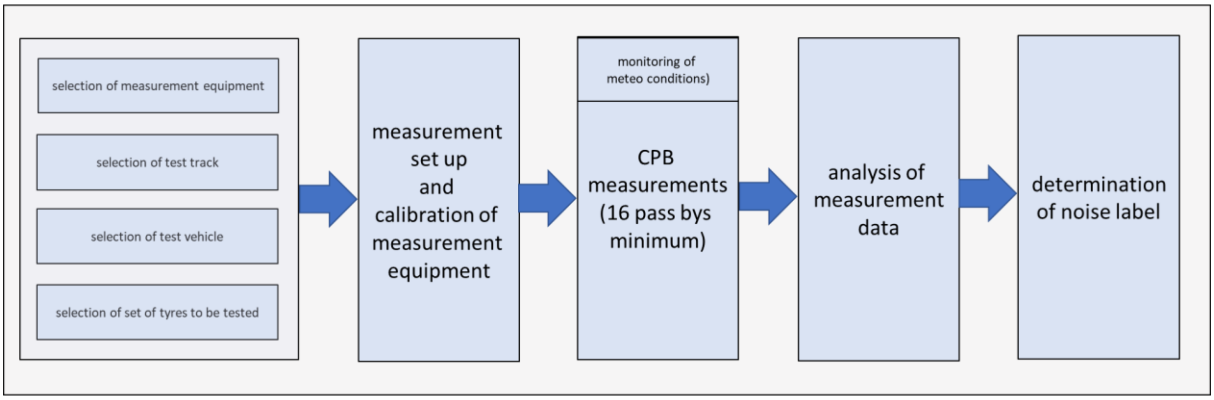

Figure 1 Schematic representation of the tyre noise label procedure

A thorough analysis is done in this project of possible contributions to the uncertainty of the result, of which 41 have been identified, which have been categorized in eight “uncertainty groups” or “uncertainty categories” (Table 1):

Table 1 Uncertainty source and proposed classification in categories

Group #	Uncertainty group	Source of uncertainty
1	equipment	Calibration
1	equipment	SPL meter accuracy
1	equipment	tachometer accuracy
1	equipment	thermometer accuracy
1	equipment	anemometer accuracy
2	experimental set up	vertical position of microphone
2	experimental set up	horizontal position of microphone
3	meas. conditions	temperature influence: correction error
3	meas. conditions	temperature influence: representativity of method
3	meas. conditions	humidity influence (incl. possible water remaining in voids)

3	meas. conditions	wind speed influence
3	meas. conditions	wind direction influence
3	meas. conditions	ambient noise
3	meas. conditions	disturbing noise events
4	measurement	random fluctuations of L_{AFmax} measurements
4	measurement	drift of SLM during measurement
4	measurement	deviation of vehicle from "perfect" straight line during coast by
4	measurement	vehicle speed deviations
5	test vehicle	car underbody-ground clearance
5	test vehicle	car engine and transmission contribution
5	test vehicle	mechanical contributions from car (rattling etc)
5	test vehicle	car aerodynamical contributions
5	test vehicle	wheel housing
5	test vehicle	wheel alignment
5	test vehicle	wheel base
5	test vehicle	Influence of the width and material of selected test rim
6	test track	influence of macro- and megatexture
		influence of absorption of test track
		influence of absorption of propagation area
6	test track	influence of microtexture (affecting stick-slip)
6	test track	influence of rubber-surface adhesion (affecting stick-snap)
6	test track	influence of surface contaminations (dirt, rubber, etc)
6	test track	influence of unevenness (causing variation of loads)
6	test track	influence of possible melted bitumen in hot weather
7	test tyres	effect of assigning noise label of different tyre in same line
7	test tyres	sampling of tyres from batch (manufacturing tolerance)
7	test tyres	batch to batch differences (manufacturing tolerance)
7	test tyres	tyre rubber hardness
7	test tyres	tyre run in differences
7	equipment	tyre inflation
7	equipment	tyre load (incl different load on the axles)
8	calculation	rounding of result to lower integer
8	calculation	arbitrary correction

2.2 Estimating the uncertainties in the tyre noise label determination

Following a methodology based on [ISO, 2008], the table shown in Annex I has been drafted. For each uncertainty contribution, we have assessed the following:

- Nature: is the uncertainty “systematic” for a given measurement campaign or is it “random”? In the latter case, the uncertainty contribution can be reduced by increasing the number of coast-by movements and arithmetic averaging of the results. The minimum number of coast-by[1] measurements has been fixed to 16, but this has hence only effects on the “random” uncertainty contributions
- The estimand of the uncertainty, i.e. the expected value of the combined uncertainties
- The probability distribution of the input quantity[2]. Exact data are often not available so an estimation has to be made. If the input quantity can lie on both sides of the true value and the probability is higher that it is closer to the true value than further away from it, we can assume a normal distribution in a good approximation. If all values for the input quantity are equally

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[1] Pass by measurement, but with engine switched off

[2] e.g. air temperature, speed of the vehicle,…

likely within a given interval, we have a rectangular distribution. In some cases, the input quantity can only lie above or only below a fixed value, and in that case, one has a single-sided distribution. If the input quantity is more likely to lie close to the limit value than further away, a half-normal distribution is a good approximation.

- The uncertainty contribution on the measurand[3] due to input quantity x_i (for *one coast-by measurement*), $c_i u_i$, expressed as *a standard deviation[4]*. There are two methods described in [ISO-2008] to estimate this value ("Type A": statistical observation of a series of measurements and the preferable method and "Type B", "other" methods). In most cases an estimation has been made with the Type B method (see for details the information provided in the last column of the table)
- The uncertainty contribution for *the average result of N = 16 coast-by measurements*, reducing the uncertainty contributions of the random type with a factor $\sqrt{N} = 4$ and leaving the contributions of the "systematic" type unchanged.
- In this calculation we cover the case that the measurements may be made on any approved ISO test track worldwide, and not just one single test track.

2.3 Confidence interval

The combined uncertainty u_c is calculated according to equation (10) in [ISO-2008]. The combined uncertainties per uncertainty group were calculated as well. The parameter u_c is the uncertainty - expressed as a standard deviation - of the measurand and according to the Central Limit Theorem, the measurand is normally distributed (at least in a good approximation if not all of the constituents are normally distributed). To determine the confidence interval, the right coverage factor[5] must be selected, see Table G.1 in [ISO, 2008]. The 95 % confidence interval can be obtained by multiplying u_c with the factor $k_p = 1.95$. In the following paragraphs with uncertainty – unless otherwise stated – the value of u_c is meant.

2.4 Uncertainty analysis

All uncertainty contributions have been assessed and an estimation has been made for the C1 and C2 tyres (see Annexes I and II respectively).

For most uncertainty contributions, a reasonable or even a good estimation could be made, but there surely are some gaps:

- The influence of the air humidity on the result is not completely clear, but it is our expert judgement that the effect is presumably small and even negligible as, in practice, measurements will be done in (assumed) dry conditions. But when somebody is tempted to measure when conditions are in a "grey zone" the effect may be significant.

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[3] the tyre noise label

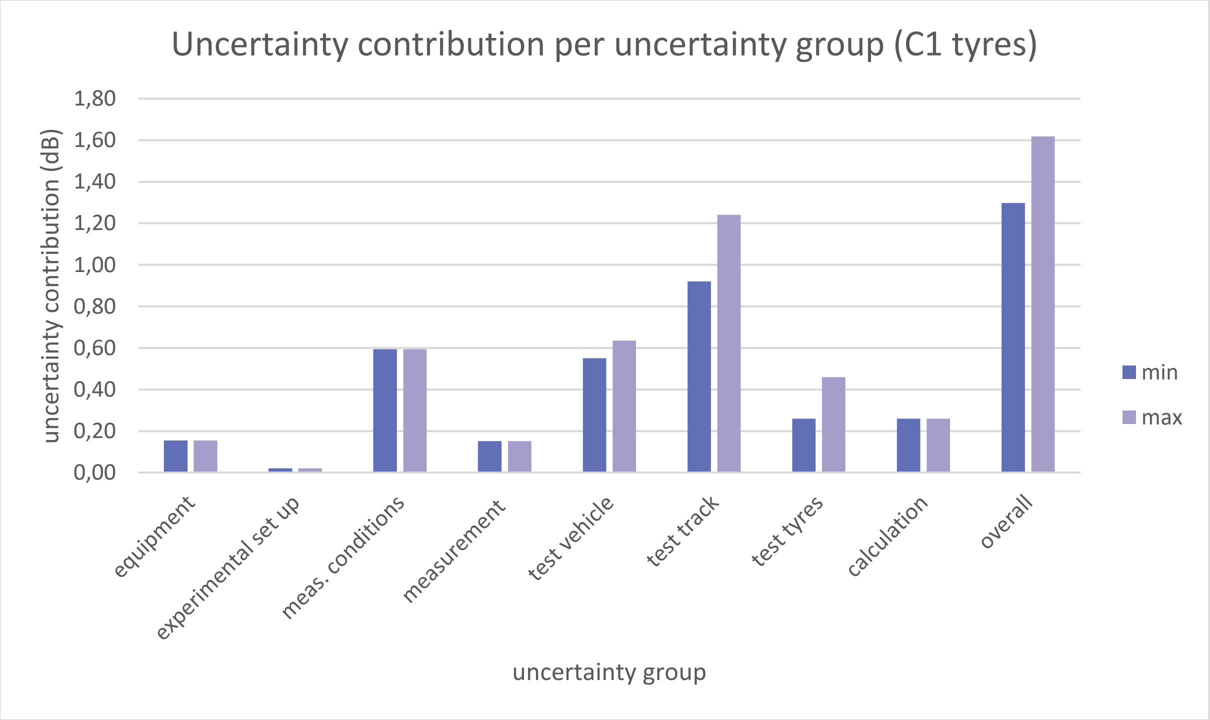
[4] note that I opted not to determine the sensitivity coefficient separately, but made an the estimation for the product c_i u_i

[5] number larger than one by which a combined standard measurement uncertainty is multiplied to obtain an expanded measur

- The contribution of the imperfect correlation between air temperature and the tyre/road noise, which is treated in a separate STEER report, might be significant. This will be considered in close cooperation with ISO/TC 43/SC 1/WG 27.
- For the uncertainty contribution of the car as a whole, we could use the value extracted from a database from a tyre manufacturer, yielding a value of 0.60 dB, or we could use the value proposed by ETRTO (0.51 dB).
- About the influence on the uncertainty of the tyres: one extracted an overall value for the tyre uncertainty from the data base of a tyre manufacturer and found an uncertainty of 0.46 dB for measurements within the same tyre family. The value proposed by ETRTO for the total tyre influence is only 0.26 dB.
- For the contribution of the test track: first, one should remark that Reg. 117 does not refer to the most recent version of ISO 10844 but to the 1994 version. ETRTO suggests an uncertainty contribution of 0.92 dB. This is in line with the expert view expressed in [Sandberg, 2017]. A round robin test on eight European ISO test tracks with four different tyres (slick, summer tyre, winter tyre and a van tyre) was carried out in 2005 by M+P. Most relevant are the results obtained with the summer and winter tyre and one found a difference (max-min) of 7.8 and 3.8 dB. The large spread for the summer tyre was however caused by one outlier; if this one is removed a 4 dB difference max-min is also found for this tyre, which is actually in line with the previous. Measurements on 186 AC8 pavements in Switzerland by G+P yielded a standard deviation of 1,24 dB, which can be considered as an upper limit [Roth, 2020].
- The analysis is carried out separately for C1 and C2 tyres, but the only difference in the calculation is the uncertainty contribution of the wheel track: for C1 tyres this contribution is estimated to be only 0,21 dB and for C2 tyres 0.56 dB.

3 Results

There are still some gaps in the knowledge of the uncertainty contributions, in other words: there are still some “uncertainties on the uncertainties”. Nevertheless, the authors are confident that the uncertainty calculations on the label as outlined in Annexes I and II yield a reliable estimation of the uncertainty contributions from the seven identified uncertainty groups. The result of the calculation with the lowest estimated and the highest estimated values, both for C1 and C2 tyres, are shown in Figure 2.



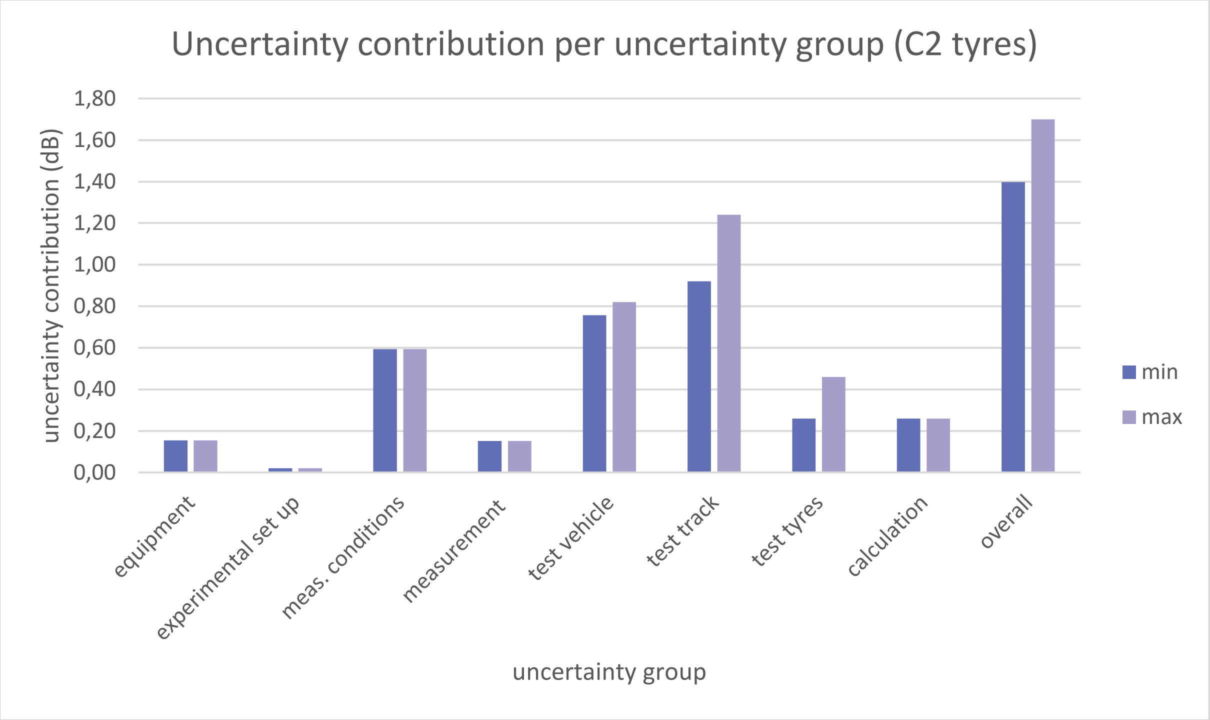


Figure 2 Uncertainty contributions per uncertainty group for the C1 (top) and C2 tyres (bottom)

The test track uncertainty appears to yield by far the main contribution, both in the optimistic (min) as the pessimistic case (max) and for C1 and C2 tyres. One should address this in the first place. An effective solution to reduce this main uncertainty contribution could be an acoustic calibration procedure. The uncertainty contributions from the measurement conditions and the test vehicle appear to be comparable and share a second place. The latter is somewhat more important in the case of the C2 tyres. They should be addressed as well. The reduction of the uncertainty caused by the measurement conditions seems to be relatively easy, as it comes by the temperature effect and may be as well – but this must be confirmed – by wind influence in the microphone. The uncertainty can be drastically reduced by adapting the temperature correction to the state of the art and by the narrowing the allowable temperature window, which is now rather wide. One should check whether the maximum allowable wind speed should be lowered to 3 m/s instead of 5 m/s. Ranked on the fourth place, one finds the contribution from the tyres and this contribution could be underestimated, as the available data are not fully complete. The other sources contribute in a rather marginal way and could be ignored.

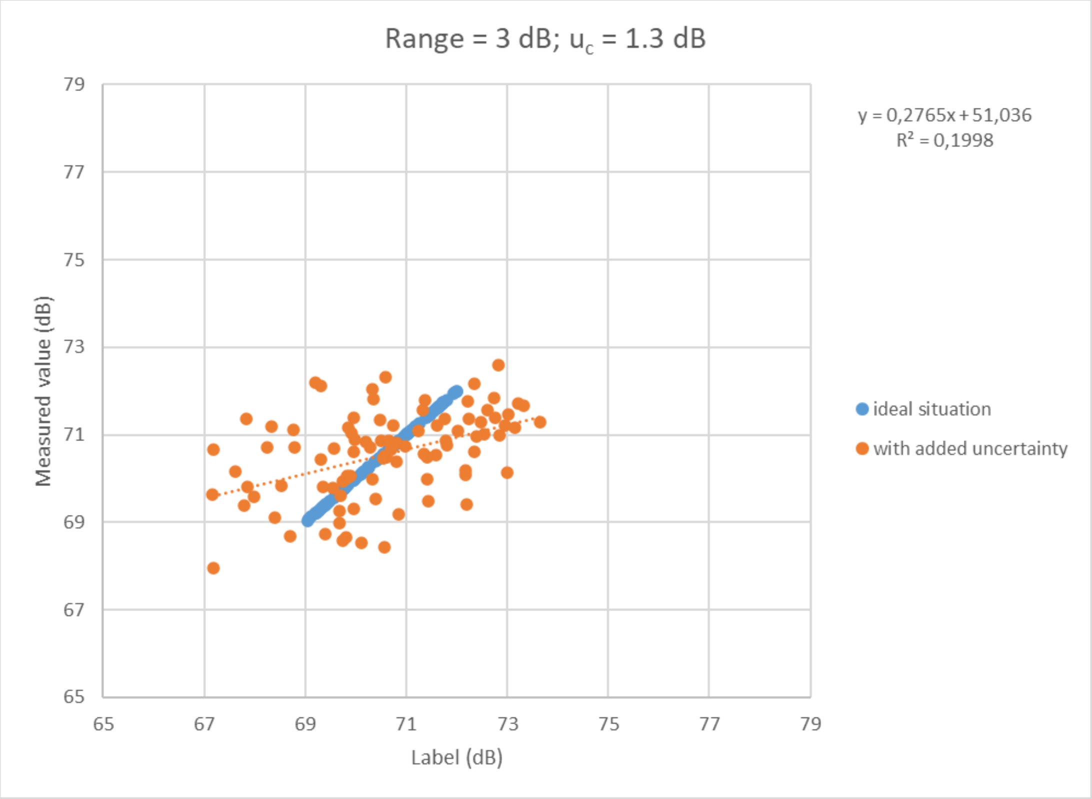
4 Monte Carlo simulation

4.1 What is a Monte Carlo method?

Monte Carlo simulations are used to model the probability of different outcomes in a process that cannot easily be predicted due to the intervention of random variables. It is a technique used to understand the impact of risk and uncertainty in prediction and forecasting models. Here we use it in a very simple way: to predict the effect of a given uncertainty on the correlation between two sets of measurands: the tyre noise label and the CPX value on an ISO test track.

4.2 Methodology

We have used an imaginary data set of tyres with labels that were used to carry out coast-by measurements in order to illustrate the effect of uncertainty of the label on the correlation by means of a Monte Carlo simulation. In the ideal situation (uncertainty zero on label and coast-by measurement), one would obtain a perfect correlation. The range of the label is unknown but could lie between 3 and 7 dB. By adding random, normally distributed uncertainties (±1.3 or ±1.6 dB on the label, i.e. the minimum respectively maximum total uncertainty on the label as calculated in §3 for the C1 tyres and 0.58 dB[6] on the CPX measurements), we get an impression what these uncertainties do with the correlation, We hereby have to realize that the range of the label heavily influences the obtained R² as well. In Figure 3 the two cases with the range = 3 dB are shown with total uncertainty on the label 1.30 and 1.6 dB. In Figure 5 the two cases with the range equalling 7 dB are shown. The R² may vary somewhat from simulation to simulation, but typical graphs with average R² are depicted.



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[6] Combination of uncertainty on CPX method (typically 0.5 dB according to ISO 118919-2:2017) and the uncertainty on the SRTT tyre (0.4 dB according to ISO/TS 11819-3:2017)

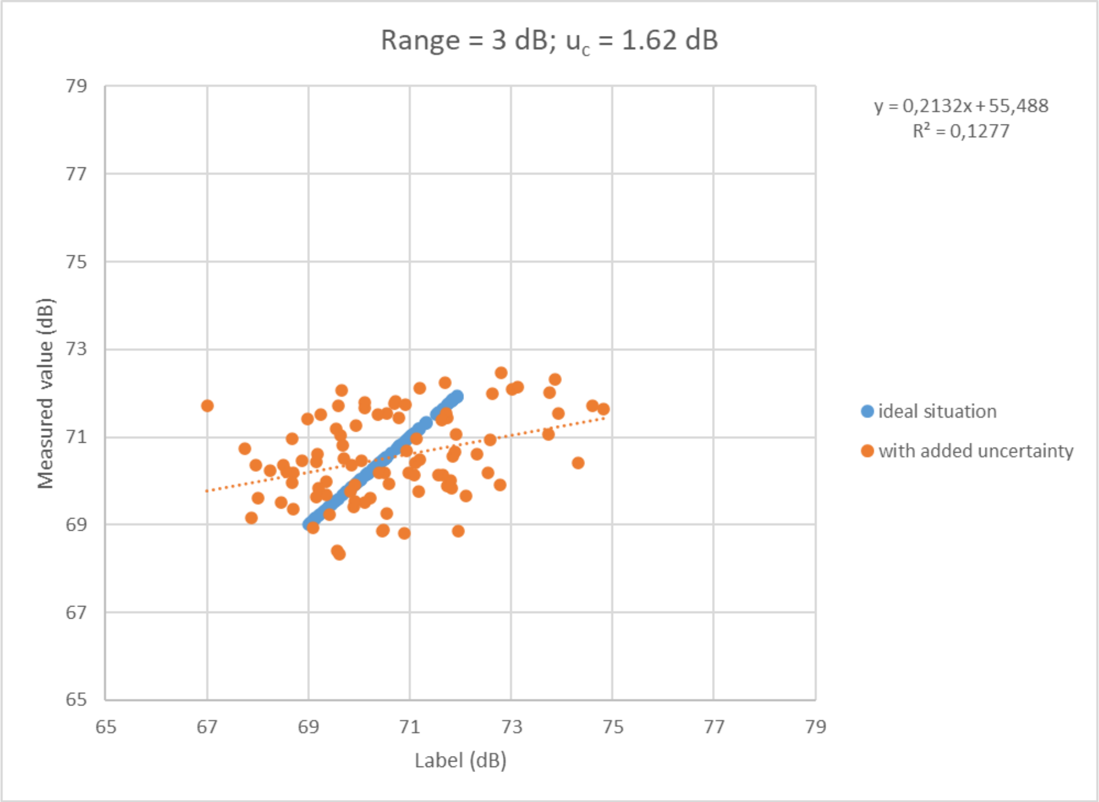
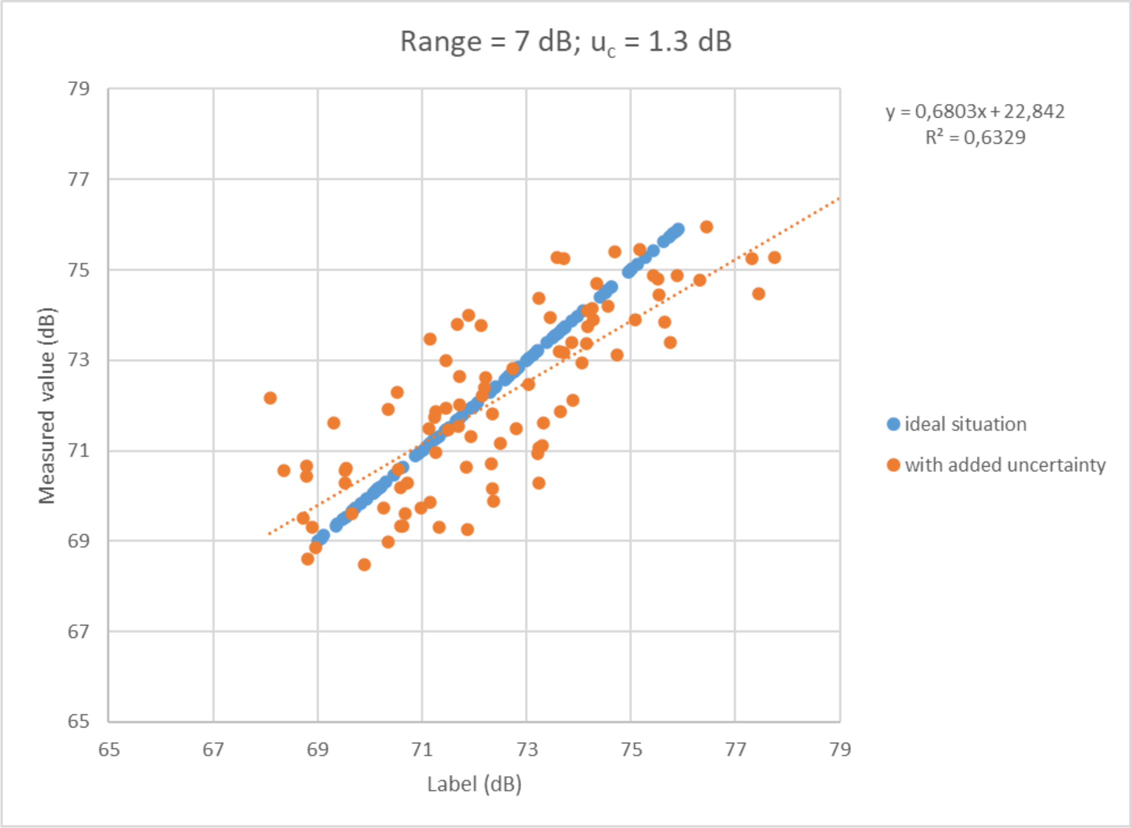


Figure 3 Monte Carlo simulation of correlation between a tyre label with the calculated uncertainties and coast-by measurements (range on true label = 3 dB and uncertainty on label = 1.3 dB (top) and 1.62 (bottom),, expressed as standard deviation; uncertainty on CB measurement = 0.58 dB, also expressed as standard deviation)



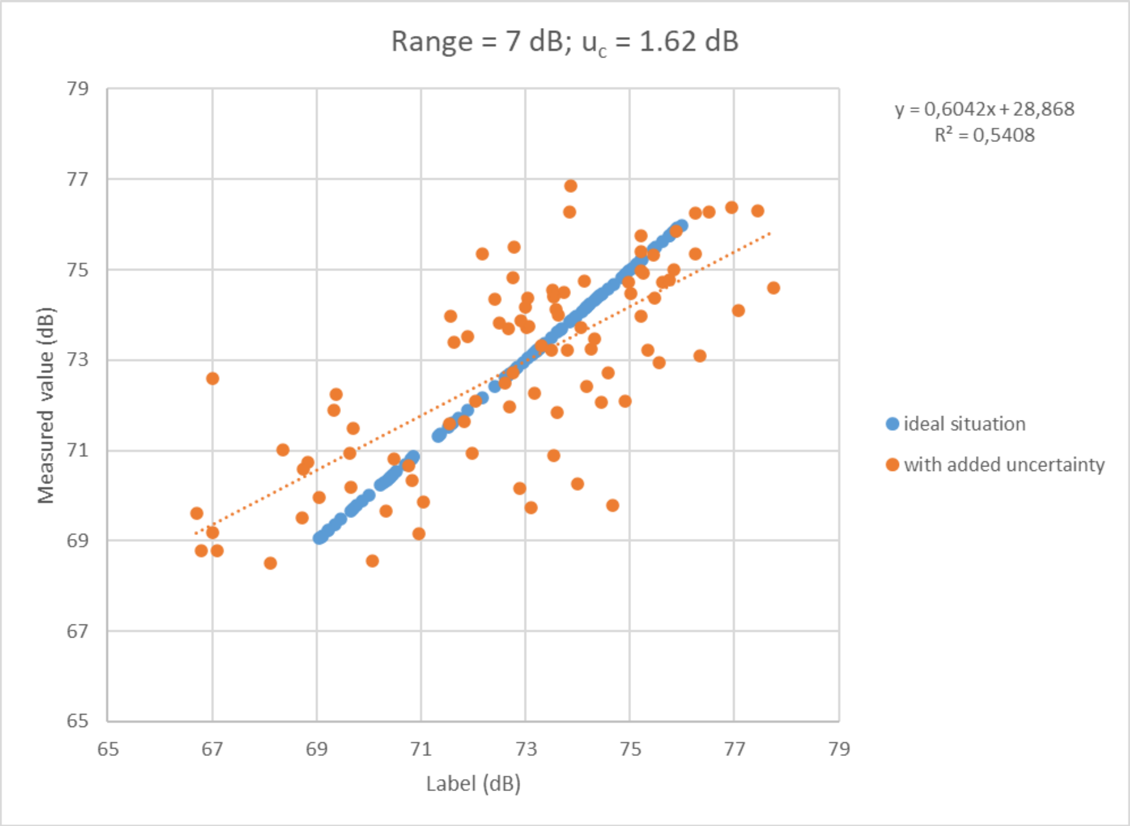


Figure 4 Monte Carlo simulation of correlation between a tyre label with the calculated uncertainties and coast-by measurements (range on true label = 7 dB and uncertainty on label = 1.3 dB (top) and 1.62 (bottom),, expressed as standard deviation; uncertainty on CB measurement = 0.58 dB, also expressed as standard deviation)

4.3 Comparison with experimental results

Some findings from the Nordtyre project (Figure 5, [Kragh, 2015]) and more recent Swiss results (Figure 6, [Hammer and Bühlmann, 2018; Goubert, 2020]) show a very poor correlation between the tyre label and the measured CPX values. These result most resemble the simulation with a small range of the tyre label (3 dB), combined with the highest uncertainty (u_c = 1.6 dB), see Figure 3, bottom.

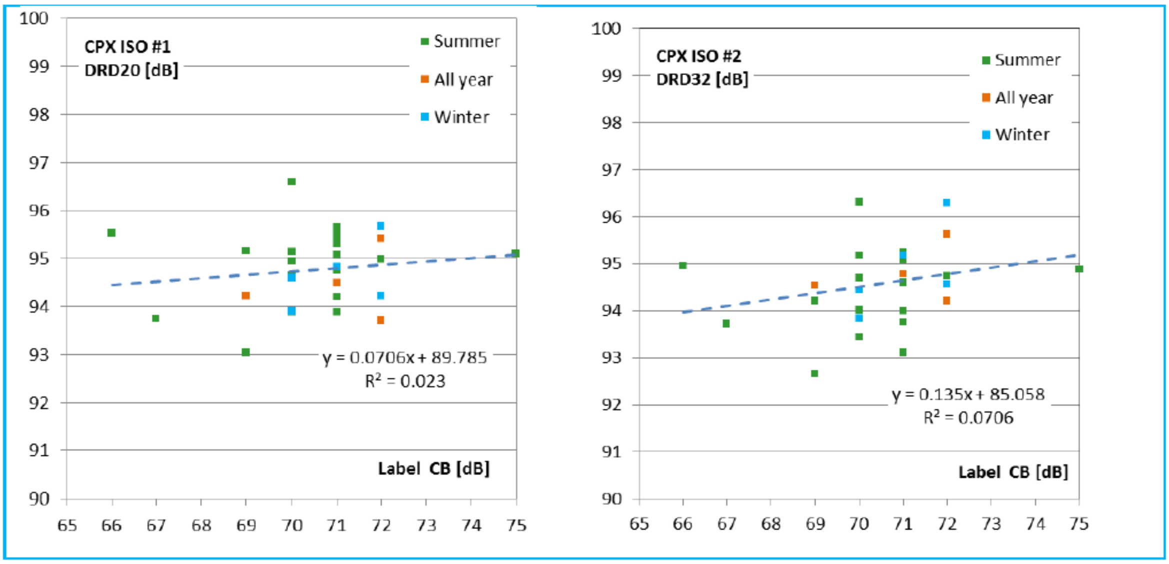


Figure 5 *Measured CPX levels on 2 ISO test tracks as a function of the tyre label values issued by tyre manufacturer [Kragh et al, 2015].*

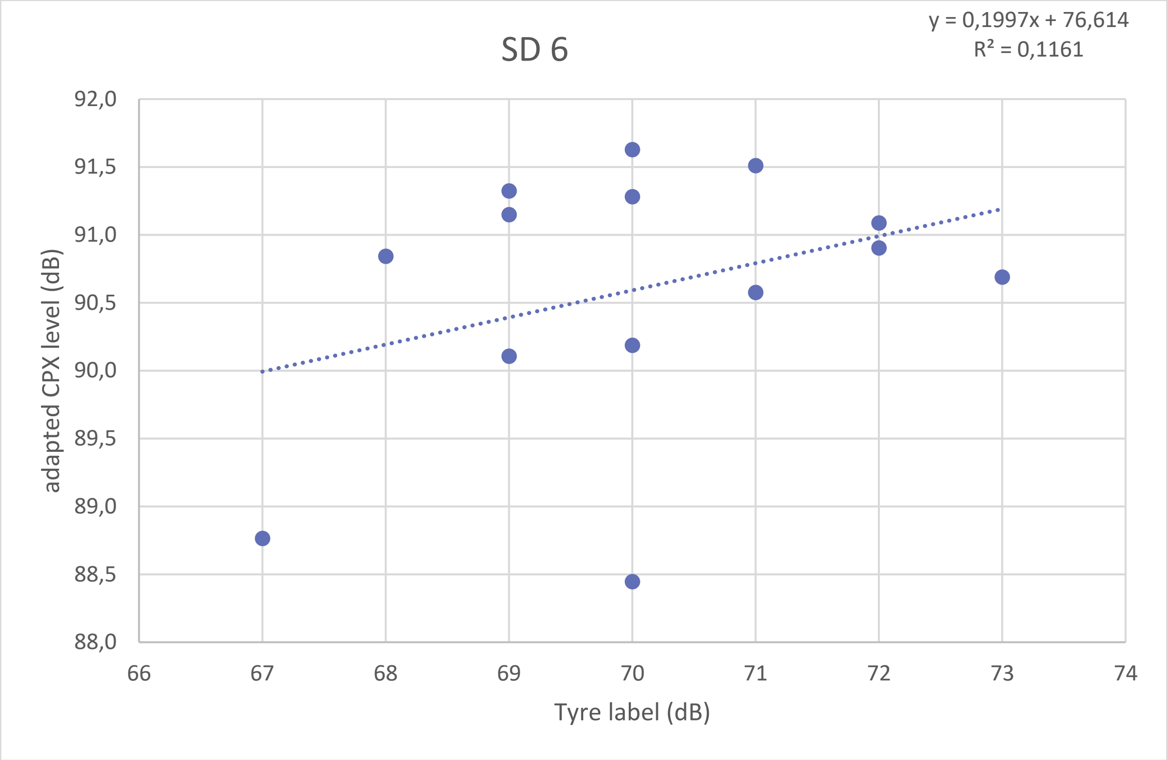


Figure 6 Adapted CPX levels on 6 mm surface dressing (SD 6) as a function of the tyre (noise) label. Although the CPX measurements are not carried on a genuine ISO test track, the complete lack of correlation illustrates the poor reproducibility of the tyre noise label [Hammer and Bühlmann, 2018]; reanalyzed data in [Goubert and Berge, 2020]

5 Conclusions and preliminary recommendations

In this deliverable the various uncertainty contributions of the current tyre noise labelling procedure were investigated, both for C1 and C2 tyres. The results for the C1 tyre are summarized in Table 2, together with possible options to reduce them. The case of the C2 tyres is very similar with the exception that in this case the uncertainty contribution of the vehicle is a bit higher, due to wheel base variations. For C2 tyres one could in particular consider measures to reduce this uncertainty contribution, i.e. narrowing the allowable wheel base variations of the test vehicle.

Table 2 Uncertainties for the case of the C1 tyre and possible actions to reduce them

Uncertainty group	**Uncertainty contribution**	**Options for reduction of the uncertainty**	**Est. improvement uncertainty**	**Practical implications**
Text track	0.92 up to 1.30 dB	• Narrowing down specifications in ISO 10844 • Acoustic calibration procedure of test track • Second rough ISO 10844 test track	☆☆ ☆☆☆☆ ☆	Difficulties meeting requirements, increases costs of construction (- -) Repeated calibration measurements necessary (-) Doubles costs for construction and tyre testing (- - -)
Measurement Conditions	0.59 dB	• Stricter requirements wind speed (correction not possible)	☆☆	Only limited number of measurement days for open test tracks (- - -) Possible changes to temperature measurement (-)

		• Improved temperature correction procedure • Update temperature corrections	☆ ☆	Possible changes to temperature measurement (-)
Test vehicle	0.55 up to 0.63 dB	• Narrowing specifications of test vehicle	☆☆	
Calculation	0.26 dB	• Small contribution, no further reduction needed		
Test tyres	0.26 up to 0.46 dB	• Narrowing the definition of “tyre family”	☆☆☆	Increase number of required tests and hence cost (- -)
Measurement	0.15 dB	• Small contribution, no further reduction needed		
Equipment	0.15 dB	• Small contribution, no further reduction needed		
Experimental setup	0.02 dB	• Small contribution, no further reduction needed		

6 References

- Regulation (EC) No 1222/2009 of the European Parliament and of the Council of 25 November 2009 on the labelling of tyres with respect to fuel efficiency and other essential parameters
- Regulation No 117 of the Economic Commission for Europe of the United Nations (UNECE) – Uniform provisions concerning the approval of tyres with regard to rolling sound emissions and/or adhesion on wet surfaces and/or rolling resistance of 12 August 2016 and in particular Annex 3 “Coast-by test method for measuring tyre-rolling sound emission”
- ISO/IEC Guide 98-3:2008 (E) Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM: 1995)
- Draft ISO/TS 13473-2
- ISO 11819-2:2017 Acoustics - Measurement of the influence of road surfaces on traffic noise - Part 2: The close-proximity method
- ISO/TS 11819-3:2017 Acoustics - Measurement of the influence of road surfaces on traffic noise – Part 3: Reference tyres
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- van Blokland, G; Peeters, B., "Comparison of properties of ISO 10844 test tracks", M+P report M+P.MVM.04.2.1 (Jan 2006), work carried out for WG42TT
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- Hammer, E.; Bühlmann, E. (2018): The noise reduction potential of “silent tyres” on common road surfaces, Proceedings of Euronoise 2018 , Crete
- Goubert, L.; Berge, T. Report on the representativity of the ISO test track compared to common
- European road pavements, STEER project document (2020)
- Sandberg, U. “Calibrating the ISO 10844 test surfaces used for vehicle and tyre noise testing”, Proceedings of INTERNOISE 2017, Chicago (2017)
- Roth, V., personal communication (2020)

Annex I – C1 Tyre

Group #	Uncertainty group	Source of uncertainty	Concerned § in Annex 3 of Reg. 117	Nature	Estimand	Prob. Distr.	Unc. Contr. c_i u_i	Unc. contr. for N = 16	See § in ISO/IEC Guide 98-3:2008	Remarks
1	equipment	calibration	1,10	syst.	0,00	normal	0,10	0,10		tolerance for calibration
1	equipment	SPL meter accuracy	1.1	syst.	0,00	normal	0,10	0,10		intrinsic accuracy of Class I of IEC 61672-1:2002 is present standard; in Reg 1222/2009 referred to IEC 60651:1979/A1:1993; systematic error
1	equipment	tachometer accuracy	1.2	syst.	0,00	normal	0,05	0,05		+/- 1 km/h on 80 km/h leads to +/- 0,16 dB
1	equipment	thermometer accuracy	1.3	syst.	0,00	normal	0,03	0,03		
1	equipment	anemometer accuracy	1.4	syst.	0,00	normal	0,00	0,00		anenometer tolerance is +/- 1 m/s
2	experimental set up	vertical position of microphone	1.1.3	syst.	0,00	normal	0,00	0,00		height 1,2 m +/- 0,02 m
2	experimental set up	horizontal position of microphone	1.1.3	syst.	0,00	normal	0,02	0,02	4.3.9. NOTE 1	distance 7,5 m +/- 0,05 m
3	meas. conditions	temperature influence: correction error	2.2 and 4	syst.	0,00	rectangular	0,58	0,58	4.3.8 eq. (8)	temperature correction = -0,10 dB/°C on dense asphalt for C1 and C2 tyres (ISO 13471-2); in §4 correction for temp effects. Temperature range 5 to 40°C; ref. temp is 20°C; correction factors given for C1 and C2 tyres
3	meas. conditions	temperature influence: representativity of method	2.2 and 4	syst.	0,00	rectangular	0,00	0,00		
3	meas. conditions	humidity influence (incl possible water remaining in voids)	2.1	syst.		half-normal	0,00	0,00	F.2.4.4	not specified in Annex 3, except that surface must be "dry" and "clean"; presumably influence on "dry" road surface is negligable; asymmetric probability distribution as can only lead to increase of SPL
3	meas. conditions	wind speed influence	2.2	syst.		half-normal	0,00	0,00	F.2.4.4	wind speed < 5 m/s ; potentially high influence, even with windscreen; asymmetric probability distribution as can only lead to increase of SPL; possibly exponantial distribution (input from B&K pending)
3	meas. conditions	wind direction influence		syst.	0,00	normal	0,00	0,00		presumably insignificant @ such small distance (7,5 m)
3	meas. conditions	ambient noise	2.3.1	syst.	0,11	half-normal	0,14	0,14	F.2.4.4	ambient noise must be at least 10 dB lower than L_{Amax}, for the case it is exact 10 dB lower it biases Lamax with 0,41 dB
3	meas. conditions	disturbing noise events	2.3.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	all measurement influenced by an external noise event shall be discarded
4	measurement	random fluctuations of LAFmax measurements		random	0,00	normal	0,17	0,04		roughly estimated to be between 0,3 up to 0,5 dB (could be determined by repeated mesurements of L_{Amax} with controlled source in controlled environment) (possibility to carry out experiment if B&K cannot provide this info)
4	measurement	drift of SLM during measurement	1.1.1	syst.	0,00	rectangular	0,14	0,14	4.3.7.	0,5 dB deviation allowed between calibrations before and after measurements
4	measurement	deviation of vehicle from "perfect" straight line during coast by		random	0,00	normal	0,04	0,01		deviation of straight line with +/- 10 cm leads to deviation of +/- 0,12 dB; 10 cm might be an appropriate estimation
4	measurement	vehicle speed deviations		random	0,00	normal	0,05	0,01		presumed that the driver keeps the speed +/- 1 km/h
5	test vehicle	car underbody-ground clearance		syst.	0,48	normal	0,60	0,60		uncertainty according to ETRTO analysis: 0,51 dB; comprises detailed contribution of category "test vehicle". From a tyre manufacturer database we derived the value 0,60 dB, which is pretty consistent

5	test vehicle	car engine and transmission contribution		syst.	0,00	half-normal	0,00	0,00	F.2.4.4	for pass-by measurements: DRD graph: @80 km/h: engine contr. = 67 dB and car contr. = 74 dB; for coast by measurements: engine is switched off: contribution is 0
5	test vehicle	mechanical contributions from car (rattling etc)	2.4.4.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	presumably negligible taking into account precautions prescribed in cited §
5	test vehicle	car aerodynamical contributions	2.4.4.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	presumably low @ 80 km/h
5	test vehicle	wheel housing	2.4.4.1 d)	syst.	0,00	half-normal	0,00	0,00		no additional sound absorbing material to be mounted in wheel house or under car body, but absorbing character of wheel causing can differ from vehicle to vehicle and hence add uncertainty to the result; dimension and shape of wheel housing might differ from vehicle to vehicle, leading to differences in reverberation field and hence noise emission
5	test vehicle	wheel alignment	2.4.4.1 c)	syst.	0,00	half-normal	0,00	0,00		wheel alignment should be in accordance with vehicle manufacturers specifications, but on there are tolerances on the wheel alignment angles (toe in, camber, caster) which may influence the result.
5	test vehicle	wheel base	2.4.3	syst.	0,17	rectangular	0,21	0,21	4.3.8 eq. (8)	for C1 tyres wheel base should be lower than 3,5 m. For C2 tyres lower than 5 m. Strange that one does not specify a minimum value. Difference in L_{Amax} between 2,5 and 3,5 m can be estimated to be 0,72 dB
5	test vehicle	Influence of the width and material of selected test rim		syst.	0,00	normal	0,00	0,00		contribution presumably small. Possibly later new input.
6	test track	influence of texture (macro- and mega-)		syst.	0,00	half-normal	1,24	1,24		important remark regarding the test track: the standard referenced in Annex 3 is the ISO 10844:1994 version which is obsolete and has been replaced by ISO 10844:2005
6	test track	influence of microtexture (affecting stick-slip)		syst.	0,00					
6	test track	influence of rubber-surface adhesion (affecting stick-snap)		syst.	0,00					
6	test track	influence of surface contaminations (dirt, rubber, etc)		syst.	0,00					
6	test track	influence of unevenness (causing variation of loads)		syst.	0,00					
6	test track	influence of possible melted bitumen in hot weather		syst.	0,00					
6	test track	influence of absorption of test track		syst.	0,00	half-normal				ETRTO analysis estimates uncertainty contribution of 0.92 dB. A round robin test on eight European ISO test tracks with four different tyres (slick, summer tyre, winter tyre and a van tyre) was carried out in 2005 by M+P. Most relevant are the results obtained with the summer and winter tyre and one found a difference (max-min) of 7.8 and 3.8 dB. The large spread for the summer tyre was however caused by one outlier; if this one is removed a 4 dB difference max-min is also found for this tyre, which is actually in line with the previous. Measurements on 186 AC8 pavements in Switzerland by G+P yielded a standard deviation of 1,3 dB, which can be considered as an upper limit. Therefore calculation has been done with uncertainty contribution of test track equalling 0,92 and 1,3 dB.
6	test track	influence of absorption of propagation area		syst.	0,00	half-normal				

7	test tyres	effect of assigning noise label of different tyre in same line		syst.	0,00	normal	0,00	0,00		potentially significant contribution to uncertainty. Input will follow from Swedish project
7	test tyres	sample to sample differences		syst.	0,00	normal	0,46	0,46		value from tyre manufacturers data base is ,46 dB; uncertainty for measurements with tyres with nominally the same dimensions and ratings: uncertainty according to ETRTO analysis: 0,26 dB;
7	test tyres	tyre rubber hardness		syst.	0,00	half-normal	0,00	0,00		
7	test tyres	tyre run in differences	2.5.4	syst.	0,00	half-normal	0,00	0,00		tyres have to be run in for at least 100 km. What if one runs them in for a much longer distance?
7	equipment	tyre inflation	2.5.3	syst.	0,00	normal	0,00	0,00		literature ref of relation between tyre/road noise emission and tyre pressure?
7	equipment	tyre load (incl different load on the axles)	2.4.2 and 2.5.2	syst.	0,00	normal	0,00	0,00		literature ref of relation between tyre/road noise emission and tyre load?
8	calculation	rounding of result to lower integer	4.5	syst.	-0,45	rectangular	0,26	0,26		
8	calculation	arbitrary correction	4.4	syst.	-1,00	half-normal	0,00	0,00		
								2,62		
				E(Y)	**-0,70**		**u_c**	**1,6**	5.1.2 eq. (10) and Annex G.2	uncertainty on label expressed as standard deviation
							U_c	**3,2**		95 % confidence interval is ± U_c

Annex II – C2 Tyre

Group #	**Uncertainty group**	**Source of uncertainty**	**Concerned § in Annex 3 of Reg. 117**	**Nature**	**Estimand**	**Prob. Distr.**	**Unc. Contr. $c_i u_i$**	**Unc. contr. for N = 16**	**See § in ISO/IEC Guide 98-3:2008**	**Remarks**
1	equipment	calibration	1,10	syst.	0,00	normal	0,10	0,10		tolerance for calibration
1	equipment	SPL meter accuracy	1.1	syst.	0,00	normal	0,10	0,10		intrinsic accuracy of Class I of IEC 61672-1:2002 is present standard; in Reg 1222/2009 referred to IEC 60651:1979/A1:1993; systematic error
1	equipment	tachometer accuracy	1.2	syst.	0,00	normal	0,05	0,05		+/- 1 km/h on 80 km/h leads to +/- 0,16 dB
1	equipment	thermometer accuracy	1.3	syst.	0,00	normal	0,03	0,03		
1	equipment	anemometer accuracy	1.4	syst.	0,00	normal	0,00	0,00		anenometer tolerance is +/- 1 m/s
2	experimental set up	vertical position of microphone	1.1.3	syst.	0,00	normal	0,00	0,00		height 1,2 m +/- 0,02 m
2	experimental set up	horizontal position of microphone	1.1.3	syst.	0,00	normal	0,02	0,02	4.3.9. NOTE 1	distance 7,5 m +/- 0,05 m
3	meas. conditions	temperature influence: correction error	2.2 and 4	syst.	0,00	rectangular	0,58	0,58	4.3.8 eq. (8)	temperature correction = -0,10 dB/°C on dense asphalt for C1 and C2 tyres (ISO 13471-2); in §4 correction for temp effects. Temperature range 5 to 40°C; ref. temp is 20°C; correction factors given for C1 and C2 tyres
3	meas. conditions	temperature influence: representativity of method	2.2 and 4	syst.	0,00	rectangular	0,00	0,00		
3	meas. conditions	humidity influence (incl possible water remaining in voids)	2.1	syst.		half-normal	0,00	0,00	F.2.4.4	not specified in Annex 3, except that surface must be "dry" and "clean"; presumably influence on "dry" road surface is negligable; asymmetric probability distribution as can only lead to increase of SPL
3	meas. conditions	wind speed influence	2.2	syst.		half-normal	0,00	0,00	F.2.4.4	wind speed < 5 m/s ; potentially high influence, even with windscreen; asymmetric probability distribution as can only lead to increase of SPL; possibly exponantial distribution (input from B&K pending)
3	meas. conditions	wind direction influence		syst.	0,00	normal	0,00	0,00		presumably insignificant @ such small distance (7,5 m)
3	meas. conditions	ambient noise	2.3.1	syst.	0,11	half-normal	0,14	0,14	F.2.4.4	ambient noise must be at least 10 dB lower than L_{Amax}, for the case it is exact 10 dB lower it biases Lamax with 0,41 dB
3	meas. conditions	disturbing noise events	2.3.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	all measurement influenced by an external noise event shall be discarded
4	measurement	random fluctuations of LAFmax measurements		random	0,00	normal	0,17	0,04		roughly estimated to be between 0,3 up to 0,5 dB (could be determined by repeated mesurements of L_{Amax} with controlled source in controlled environment) (possibility to carry out experiment if B&K cannot provide this info)
4	measurement	drift of SLM during measurement	1.1.1	syst.	0,00	rectangular	0,14	0,14	4.3.7.	0,5 dB deviation allowed between calibrations before and after measurements
4	measurement	deviation of vehicle from "perfect" straight line during coast by		random	0,00	normal	0,04	0,01		deviation of straight line with +/- 10 cm leads to deviation of +/- 0,12 dB; 10 cm might be an appropriate estimation
4	measurement	vehicle speed deviations		random	0,00	normal	0,05	0,01		presumed that the driver keeps the speed +/- 1 km/h

5	test vehicle	car underbody-ground clearance		syst.	0,48	normal	0,60	0,60		uncertainty according to ETRTO analysis: 0,51 dB; comprises detailed contribution of category "test vehicle". From a tyre manufacturer database we derived the value 0,60 dB, which is pretty consistent
5	test vehicle	car engine and transmission contribution		syst.	0,00	half-normal	0,00	0,00	F.2.4.4	for pass-by measurements: DRD graph: @80 km/h: engine contr. = 67 dB and car contr. = 74 dB; for coast by measurements: engine is switched off: contribution is 0
5	test vehicle	mechanical contributions from car (rattling etc)	2.4.4.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	presumably negligible taking into account precautions prescribed in cited §
5	test vehicle	car aerodynamical contributions	2.4.4.2	syst.	0,00	half-normal	0,00	0,00	F.2.4.4	presumably low @ 80 km/h
5	test vehicle	wheel housing	2.4.4.1 d)	syst.	0,00	half-normal	0,00	0,00		no additional sound absorbing material to be mounted in wheel house or under car body, but absorbing character of wheel cousing can differ from vehicle to vehicle and hence add uncertainty to the result; dimension and shape of wheel housing might differ from vehicle to vehicle, leading to differences in reverberation field and hence noise emission
5	test vehicle	wheel alignment	2.4.4.1 c)	syst.	0,00	half-normal	0,00	0,00		wheel alignment should be in accordance with vehicle manufacturers specifications, but on there are tolerances on the wheel alignment agles (toe in, camber, caster) which may influence the result.
5	test vehicle	wheel base	2.4.3	syst.	0,45	rectangular	0,56	0,56	4.3.8 eq. (8)	For C2 tyres lower than 5 m. Strange that one does not specify a minimum value. Difference in Lamax between 2,5 and 5 m can be estimated to be -1,9 dB
5	test vehicle	Influence of the width and material of selected test rim		syst.	0,00	normal	0,00	0,00		contribution presumably small. Possibly later new input.
6	test track	influence of texture (macro- and mega-)		syst.	0,00	half-normal	1,24	1,24		important remark regarding the test track: the standard referenced in Annex 3 is the ISO 10844:1994 version which is obsolete and has been replaced by ISO 10844:2005
6	test track	influence of micro-texture (affecting stick-slip)		syst.	0,00					
6	test track	influence of rubber-surface adhesion (affecting stick-snap)		syst.	0,00					
6	test track	influence of surface contaminations (dirt, rubber, etc)		syst.	0,00					
6	test track	influence of unevenness (causing variation of loads)		syst.	0,00					
6	test track	influence of possible melted bitumen in hot weather		syst.	0,00					
6	test track	influence of absorption of test track		syst.	0,00	half-normal				ETRTO analysis estimates uncertainty contribution of 0.92 dB. A round robin test on eight European ISO test tracks with four different tyres (slick, summer tyre, winter tyre and a van tyre) was carried out in 2005 by M+P. Most relevant are the results obtained with the summer and winter tyre and one found a difference (max-min) of 7.8 and 3.8 dB. The large spread for the summer tyre was however caused by one outlier; if this one is removed a 4 dB difference max-min is also found for this tyre, which is actually in line with the previous. Measurements on 186 AC8 pavements in Switzerland by G+P yielded a standard deviation of 1,3 dB, which can be considered as an upper limit. Therefore calculation has been done with uncertainty contribution of test track equalling 0,92 and 1,3 dB.

6	test track	influence of absorption of propagation area		syst.	0,00	half-normal				
7	test tyres	effect of assigning noise label of different tyre in same line		syst.	0,00	normal	0,00	0,00		potentially significant contribution to uncertainty. Input will follow from Swedish project
7	test tyres	sample to sample differences		syst.	0,00	normal	0,46	0,46		value from tyre manufacturers data base is ,46 dB; uncertainty for measurements with tyres with nominally the same dimensions and ratings: uncertainty according to ETRTO analysis: 0,26 dB;
7	test tyres	tyre rubber hardness		syst.	0,00	half-normal	0,00	0,00		
7	test tyres	tyre run in differences	2.5.4	syst.	0,00	half-normal	0,00	0,00		tyres have to be run in for at least 100 km. What if one runs them in for a much longer distance?
7	equipment	tyre inflation	2.5.3	syst.	0,00	normal	0,00	0,00		literature ref of relation between tyre/road noise emission and tyre pressure?
7	equipment	tyre load (incl different load on the axles)	2.4.2 and 2.5.2	syst.	0,00	normal	0,00	0,00		literature ref of relation between tyre/road noise emission and tyre load?
8	calculation	rounding of result to lower integer	4.5	syst.	-0,45	rectangular	0,26	0,26		
8	calculation	arbitrary correction	4.4	syst.	-1,00	half-normal	0,00	0,00		
								2,89		
				E(Y)	**-0,42**		**u_c**	**1,7**	5.1.2 eq. (10) and Annex G.2	uncertainty on label expressed as standard deviation
							U_c	**3,3**		95 % confidence interval is ± U_c