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The future of environmental acoustic normalization: is uncertainty calculation an objective?

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Abstract
The aim of this paper is to examine methods for the estimation of the uncertainty associated with environmental acoustic measurements. It is considered best practice that any measurement should be accompanied by a quantitative indication of its quality, that is, the uncertainty of the measurement. ISO 1996-2:2007 "Acoustics - Description, measurement and assessment of environmental noise -Part 2: Determination of environmental noise levels" presents guidelines on how to determine the measurement uncertainty associated with environmental acoustic measurements, although the presentation of this value is not yet mandatory. However, this international standard is to be revised (stage 90.92 at 17 June 2012). From discussion with members of the ISO Standard working group, the last working draft ISO 1996-2:2011(11-02-02 2nd working draft) follows the uncertainty calculation methodology recommended in IMAGINE documents and it states that the estimation of measurement uncertainty should be reported. This paper presents a method, based on the IMAGINE project and working document, to perform this calculation as well as several examples that assist the users in developing their own algorithm. In concluding, this paper presents a reflection on why an estimate of the uncertainty of the measurement is essential in environmental acoustics, and comments on the approach currently being followed by the main European and International standards.

Keywords: environmental acoustics, uncertainty of measurement, standard.
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1 Introduction

When performing a measurement and reporting its result, a quantitative indication of the quality of that measurement should be presented. Not only does this indication allow the user to decide if the result is reliable for the purpose, but it also permits the measurement result to be evaluated by others or compared with reference values [1]. This has been the theme for several discussions on environmental noise measurements and there is still no consensus on the method for the estimation of uncertainty of such measurements. It is still not common to find a result of an environmental noise measurement reported with the uncertainty estimation for that measurement.

The European directive 2002/49/EC [2], establishes the common noise indicators L_{den} and L_{night} to be used by European countries to identify noise levels and to be used when taking protection measurements against noise. The IMAGINE project has developed several guideline documents on how to measure and/or calculate those parameters, establishing a common methodology. One of those documents [3] establishes a methodology for the measurement of the L_{den} and L_n parameters, and presents guidance on how to evaluate the uncertainty of an environmental noise measurement.

This IMAGINE document was one of the inspirations for the latest revision of ISO 1996-2: 2007. Douglas Manvel, member of the ISO TC43 SC1 Working Group 45 responsible for this revision, with the permission of Hans Jonasson leader of the group, has kindly made available the latest working draft [5]. According to this working draft, one of the items to be reported is the estimation of measurement uncertainty and the estimation method that was used. This could be taken as an indication that the uncertainty estimation will be a factor to be considered when reporting sound pressure levels in accordance with the revised ISO 1996-2.
In this paper, the guidance on uncertainty estimation methods for environmental acoustic measurements presented in the ISO 1996-2 working draft [5] is examined in both theory and practice. This research examines the measurement of road traffic and railway traffic noise. Due to time and budget constraints, only short-term measurements were done. The measurement methods presented in the working draft are followed, with the final result presented with an estimation of measurement uncertainty. The uncertainty estimation method for road traffic noise is also compared with the uncertainty estimation method presented by Craven [6].

2 Uncertainty Estimation

2.1 General Model

The mathematical model that represents the process of uncertainty estimation of a measurement is developed in [1] and is summarized in this section. Assuming a measurand Y is going to be determined from N measurements $X_1,X_2,X_3,..,X_N$. This process starts with establishing a mathematical relationship between the N measurements and the measurand. Thus Y will be a function, f, of those quantities which can be written as:

$$Y = f(X_1, X_2, X_3, ...X_N) \tag{1}$$

As the values $x_1,x_2,x_3,..,x_n$ are estimates of the input quantities $X_1,X_2,X_3,..,X_N$, as a consequence each estimate, x_i, will have an uncertainty associated, $u(x_i)$, which is expressed as a standard deviation. $u(x_i)$ is the standard measurement uncertainty.
Each uncertainty component will be treated following the same statistical process, whether the uncertainty component is determined through a statistical process or obtained from any other method.
All uncertainties will then be combined, through a functional relationship that is a linear combination with a sensitivity coefficient, c_i. According to [1] the functional relationship of the combined uncertainty, is " ...equal to the positive square root of a sum of terms..." (definition 2.3.4 of the [1]).

$$u_c(y) = \sqrt{\sum_{i=1}^{n} (c_i x_i)^2} \tag{2}$$

Where the sensitivity coefficient, c_i is given by:

$$c_i = \frac{\partial f}{\partial x_i} \tag{3}$$

The overall uncertainty will be expressed as an expanded uncertainty, U. This quantity will, with a statement of confidence, define an interval where the measurand Y will be. This will be obtained by multiplying the combined standard uncertainty by a numerical factor, known as the coverage factor, k:

$$U = ku_c(y) \tag{4}$$

A coverage factor of 2 is normally used, which corresponds to a coverage probability of 95%.[1]
Considering the previous paragraphs, the concept of a Type-A uncertainty can now be introduced. If the value x_i is estimated from n independent measurements obtained under the same measurement conditions, $x_{i,k}$ then the best estimation of x_i is the arithmetic mean of the n observations [1] and the standard deviation of such uncertainty is given by (more details can be found in [14]) :

Finally, the standard deviation is given by:

$$u(x_i) = s(\overline{x_i}) = \frac{s(x_i)}{\sqrt{n}} \tag{5}$$

Where $s(x_i)$ is the experimental standard deviation and n the total number of samples. This is the general form of a type A standard uncertainty.

All the uncertainties that do not meet this criteria are type B standard uncertainties. This applies when the estimates $x_1, x_2, \ldots x_n$ of the input quantities $X_1, X_2, \ldots, X_N$ are estimated by other means other than a statistical analysis, when dispersion of the values of the measurand is previously known. For example, information given by technical documentation or manuals, studies previously made, values indicated in standards such as in the case of the sound level meters uncertainty components.

2.2 Estimation of uncertainty in environment noise measurements, according to [5]

The big challenge in environment acoustic measurements is to obtain the expression for $Y= f(X_i)$, as there are so many variables that may have an influence, especially in outdoor measurements. The variability is inherent to a sound field both in time and in space, and can be identified:

- At the source: not only the source itself, but also all the other sources that contribute for the environmental sound. For example, in a seaside town, not only the road noise will be higher in summer, due to more traffic, but also the number of people will increase and as a consequence the noise generated by their activities will inevitably be higher;
- In the transmission path: that includes the meteorological effects, terrain topography and vegetation present, that will affect the sound propagation;
- At the receiver: receiver position, the measurement equipment among others. [7]

And although all these factors are present in every environmental noise measurement, this does not mean that the uncertainty will be higher. If the variability factors are not all identified and the magnitude of their variability is not known, they will become sources of uncertainty. The risk in these type of measurements exist when the uncertainty overlaps with an established limit [7].

Obtaining (equation1) can be a challenge as there are so many variables but it is perfectly feasible as long as proper methodologies are followed.

Reference [5] presents an estimation for (equation1), for an individual environment acoustic measurement as:

$$\mathbf{L} = L' + 10\lg\left(1 - 10^{-0,1\left(L' - L_{res}\right)}\right) + \delta_{sou} + \delta_{met} + \delta_{loc} \tag{6}$$

[1] Assuming the measurement process follows a normal distribution. For other types of distribution more references can be found in [1] and [14]

"Where L is the estimated value during the specified conditions for which we want a measured value; L' is the measured value including background noise, L_{res} = residual noise[2], δ_{sou}= an input quantity to allow for any error due to deviations from the ideal operating conditions of the source, δ_{met}= an input quantity to allow for any error due to meteorological conditions deviating from the ideal conditions, δ_{loc}= an input quantity to allow for any error due to the selection of receiver position. Often $\delta_{sou} + \delta_{met}$ is determined directly from measurements. L' and L_{res} are both dependent on δ_{slm}= an input quantity to allow for any error of the measurement chain (sound level meter in the simplest case). In addition L_{res} depends on δ_{res}= an input quantity to allow for any error due to residual noise."

Next [5] also presents orientation on how to estimate the sensitivity coefficients, c_i and the standard uncertainty, u_i, when measuring A-weighted sound pressure levels:

Table 1- Overview of uncertainties to be determined for a measured value [5]

Quantity	**Estimate**	**Standard uncertainty, u_i**	**Magnitude of sensitivity coefficient, c_i**
$L'+\delta_{slm}$	L'	u(L') 0,5[a)]	$\frac{1}{1-10^{-0,1(L'-L_{res})}}$
δ_{sou}	0	u_{sou}	1
δ_{met}	0	u_{met}	1
δ_{loc}	0,0-6,0	u_{loc}	1
$L_{res}+\delta_{res}$	L_{res}	u_{res}	$\frac{10^{-0,1(L'-L_{res})}}{1-10^{-0,1(L'-L_{res})}}$

a) 0,5 refers to a class 1 sound level meter. A class 2 meter would have the standard uncertainty 1,5 dB

3 Measurement procedure

As previously mentioned, two measurement exercises were done: road traffic noise and railway traffic noise. The road traffic noise was evaluated by the parameter: one hour A-weighted equivalent continuous sound pressure level ($L_{Aeq,1h}$), a short-term parameter. While the railway traffic noise was estimated using a long-term parameter, L_{den} as defined in [2], using sound exposure levels (SEL or L_{AE}) measured in field, from 51 train passages.

3.1 Instrumentation

The set of instrumentation system used to measure equivalent continuous sound pressure levels: sound level meter Brüel & Kjær, type 2250; microphone Brüel & Kjær, type 4189; calibrator Brüel & Kjær, type 4231; windscreen type UA- 0237 - 90mm. [3] The sound level meter was configured to measure in dB(A), one-third octave bands with mid frequencies from 50 Hz to 10 000Hz. The microphone was placed in a vertical position (grazing incidence). [14]

The meteorological parameters were measured with instrumentation that complies with the standard requirements.[4] Besides these instrumentation, it was also necessary for both measurements to determine the vehicles velocity, with a *velocity speed gun* by Bushnell.

[2] In [8] residual sound is defined as the total sound remaining at a given situation when the specific sounds under consideration are suppressed.
[3] All instrumentations had been checked for the compliance of the IEC 60942 (calibrators) and IEC 61672-1 (instrumentation system) less than year on a national standard laboratory.
[4] All these instruments had been checked less than a year on a primary or national laboratory..

3.2 Road Traffic Noise Measurement

3.2.1 Receiver location

On the urban developing planning is predicted the construction of a residential building next to a dual carriageway with two lanes in each direction. The facade of the future building at approximately 10 meters from the middle of the first lane and 18 meters from the middle of the second lane. It was assumed that the location of the most sensitive receiver (ground floor residents) will be at a height of 2.0 m from the current floor level. The road traffic noise was the only relevant source for the future dwelling as there are no noisy activities developed in the proximity:

Figure 1 – Road noise measurement site (image from http://maps.google.com/)

The microphone position followed [5] orientations and was a place where the possible discomfort for the future residents could be accessed. The measurement site was in a free field position[5].

3.2.2 Source operation

The source was a dual carriageway with two lanes in each direction, this is called a "urban avenue". As there is no official information about the road traffic of this carriageway, thorough notes about traffic composition, number of vehicles per category, category average velocity, road conditions, were registered during the measurement. Each vehicle was counted and was classified according to the categories defined in [10] as light, medium heavy, heavy, other vehicles and two-wheelers.

3.2.3 Transmission path and verification of favourable meteorological conditions

According to [5], when the condition expressed in the following equation is verified, then favourable conditions are always assumed:

$$\frac{h_S + h_R}{D} \geq 0{,}1 \tag{7}$$

[5] Free-field position, according to [5] is that where there are no near reflecting surfaces others than the ground, that may influence the sound pressure level. So the distance of the microphone to any reflecting surface must be twice the distance from the microphone to the dominant part of the source. When there is a small surface and the operator can show that the reflection has an insignificant effect (when accounting for the wavelength) then it can also be considered a free-field position.

where h_S is the source height, h_R is the receiver height and finally D is the distance between source and receiver.
There were mixed traffic conditions: light and heavy traffic. According to [10] the sound power of a vehicle is the sum of two types of noise: rolling noise and propulsion noise. For the two main vehicles categories (heavy and light), 80% of the rolling noise is considered to be radiated by a point source located at 0.10m. And 80% of the propulsion noise is considered to be radiated by a point source at 0,3m for a light vehicle and at 0,75 m for a heavy vehicle. So, considering the worst case scenario, h_S=0,01m and (equation 7) is verified.

3.2.4 Road noise measurement procedure and results

The measurement of the road traffic noise was done from 08:03a.m. until 09:03a.m. This corresponds to the rush hour in the morning and to a period with a higher probability of stable atmosphere. Previously to the start of the measurements, the meteorological conditions were monitored for at least 15 minutes to assure that the favourable propagation conditions were stabilized. Then during the one hour measurement, these parameters were permanently monitored and the values registered every 5 min. As this was an attended measurement, a manual calibration was performed immediately before and after the measurement. The results of the two calibration were within 0,5 dB.
The number of passages, during the one-hour measurement, is presented in the next table:

Table 2- Number of pass-bys during the one-hour measurement

Main category	Number of pass-bys
Light vehicles	1514
Medium heavy vehicles	57
Heavy vehicles	30
Other heavy vehicles	5
Two wheelers	16
Total	**1622**

Table 3- Results of the road traffic noise measurement

File N.º	Start time	Duration	L_{Aeq} (dB)	L_{A95}(dB)
001	08:03:56	01:00:00	61,5	51,1

3.3 Road Traffic Noise Measurement

3.3.1 Receiver location

Railway traffic was measured on a single railway with two tracks. This line is situated in the North of Portugal and serves one corridor "*Linha do Norte*". The measurement point is located approximately at 300 meters distance from the sea level, at a parking lot. Although the site is near the beach, the sound of sea was not relevant, however there was careful in choosing days when the sea conditions were calm. It can be seen from (Figure 2) that the measurement point was in a slightly curved part of the rail which gave the operator a better view to anticipate the trains passages from both directions.

Figure 2 – Railway measurement point (image from http://maps.google.com/)

The site is at a zone of speed limited to 80 Km/h, which allowed to have less variability in the speed of the trains. Also, no different actions in the operation of the trains were detected, i.e. they weren't breaking nor accelerating, at that point they were driving with the expected velocity.

3.3.2 Source operation

The trains were classified in four categories: high speed trains, inter-city trains, regional trains, freight trains. Along with the information on train category, it was also recorded: the train length (number of carriages), direction and movement (accelerating, braking or pass-by), brake type (disc-brakes, tread-brakes using cast iron or sinter), average speed and finally a small video and/or photograph of each passage was also recorded to allow verification of the recorded data.

3.3.3 Transmission path and verification of favourable meteorological conditions

Measurements were done at a distance of 7.5 m from the nearest rail track[11]. The ground between source and receiver was hard, mainly concrete. The track was dry, during the measurements.
Similarly to road traffic noise, a variety of sources can be dominant in railway noise, depending on several factors. According to [12], the main source types to consider in railway noise are: rolling noise, traction noise, aerodynamic noise, braking and squeal. The source height is considered a variable as it can be of 0m, in the case of rolling track noise, up to 4 m, the case of traction and aerodynamic noise. The condition (equation7) in the worst case scenario h_s=0m; h_R=2,0m and d=7,5 m, is verified, so favourable propagation conditions can be assumed.

3.3.4 Railway noise measurement procedure and results

As previously mentioned, the railway traffic noise was evaluated using the parameter sound exposure level (SEL or L_{AE}). The value considered for residual noise was $L_{A95.}$ The microphone was placed 2 m height, in a vertical position (grazing incidence).[14]

The measurements were done in two different days: day one (April) from 10:13am and 14:05pm and day 2: (May) between 16:4pm and 18:40pm. At least 5 pass-bys of each train category (high speed trains, inter-city trains, regional trains and freight trains) were measured. The start and end of each event was the operator's responsibility, which followed the methodology in [5]. As this was an attended measurement, a manual calibration was performed immediately before and after the measurement. The results of the two calibration were within 0,5 dB. The next table presents the number of valid pass-bys, by train category and regardless:

Table 4 – Railway measurement point

Train category	Number of valid pass-bys
Regional Train	30
Inter-city Train	8
High Speed Train	8
Freight Train	5
Total Regardless the train category	**51**

A resume of the measurement results can be seen in the next table:

Table 5 – Railway measurement results

	Regional	Inter-City	High Speed	Freight
Average L_{AE} (energetic mean)	84,7	98,5	89,8	102,3
Average L_{A95} (energetic mean)	57,4	61,9	60,0	65,1

4 Measurement uncertainty calculation results

4.1.1 Road traffic noise

As described in the previous section, the road traffic noise was determined as a single measurement along a road during one hour under favourable propagation conditions, while monitoring the source operation conditions. The uncertainty calculation for the road noise measurement, followed the example presented in point G2 [5].

Table 6 – Uncertainty Calculation of one hour $L_{Aeq,1h}$ measurement ISO 1996-2:2011[5]

Quantity	Estimate (dB(A))	Standard Uncertainty, u_i	Magnitude of sensitivity coefficient, c_i	Uncertainty contribution, C_iU_i
$L'+\delta_{slm}$	L'= 61,5	0,50	1,10	0,55
δ_{sou}	1622 vehicles	0,25[b)]	1,00	0,25
δ_{met}	favourable	2,00	1,00	2,00
δ_{loc}	+0,0 (free-field)	0,00	1,00	0,00
$L_{res}+\delta_{res}$	L_{res} =51,1	2,00	0,22	0,20
Combined uncertainty (root sum of squares)				2,10
Expanded Uncertainty (95% confidence [k=2])				4.20
Final result				$L_{Aeq,1hour}$=61,5 dB(A) ± 4,2 dB(A)

b) The standard uncertainty for road noise was determined:

$$u_{sou} \cong \frac{C}{\sqrt{n}} \tag{8}$$

where C=10 for mixed traffic conditions and n is total number of passages.

For the same measurement data, an alternative method to estimate uncertainty, presented in [6]:

Table 7 – Uncertainty Calculation of one hour $L_{Aeq,1h}$ measurement (according to Craven [6])

Source of uncertainty	**Value (half width)**	**Conversion (dB(A))**	**Distribution (divisor)**	**Standard uncertainty (dB(A))**	**Comments**
Source					
Traffic Flow	10% in 1622	0,44	Rectangular ($\sqrt{3}$)	0,25	a)
$\frac{\%HGV}{Mean\ Speed}$	5%@ 45km/h	0,42	Rectangular ($\sqrt{3}$)	0,24	b)
	15%@60 km/h				
Transmission path					
Weather	3 dB(A)	3,00	Rectangular ($\sqrt{3}$)	1,73	c)
Ground Topography	no change	n/a	-----	n/a	d)
Receiver					
Position	1 m in 10 m	0,87	Rectangular ($\sqrt{3}$)	0,50	e)
Reflective surface	free field condition verified	none	-----	n/a	f)
Instrument	1.9 dB(A)	n/a	Rectangular ($\sqrt{3}$)	1,10	g)
Background	minimal	ignore	-----	n/a	h)
Combined uncertainty (root sum of squares)				2.14	
Expanded Uncertainty (95% confidence [k=2])				4.28	
Final result				$L_{Aeq,1hour}$=61,5 dB(A) ± 4,3 dB(A)	

a) and **b)** reference [6] identifies the change in traffic flow and velocity of heavy vehicles, as being the most probably source of variability in the road traffic noise. It considers only two main types of vehicles : the heavy (unladen weight > 1525 kg) and the others. **c)** Value considered for favourable meteorological conditions. **d)** The ground topography, between source and receiver, is not expected to change after the construction of the building. **e)** To evaluate the uncertainty associated with the position of the sound level meter in relation to the future site of the most exposed facade of the building was evaluated. It is considered that the site is at 10 meters from the middle of the closer lane with a standard uncertainty of ± 1 m. Using the inverse square law, this influence can be converted in dB(A) and then re-scaling to a symmetrical uncertainty interval of equal width. **f)** It was verified the condition of free-field. **g)** As considered in [6]. **h)** The background noise could not be determined on site, as it was not possible to stop road traffic. Considering the parameter $L_{A95\%}$ as background noise, as suggested in [5], it can be considered that the background noise influence over the $L_{Aeq,1hour}$ was minimal as there is a difference between the $L_{Aeq,1hour}$ and the $L_{A95\%}$ of 10,4 dB(A).

4.1.2 Railway traffic noise

4.1.2.1 Standard uncertainty associated with the source operation

Reference [5] mentions that the standard uncertainty associated with the source operation, is determined according to equation (8). For railway traffic noise, C= 10 if the sampling was made regardless the operating conditions and C=5 if the sampling takes into account the relative occurrence of train categories. When comparing equation (8) with equation (5), it can be deducted that C corresponds to the experimental standard deviation of SEL levels. However, the standard also mentions that a more accurate uncertainty can be determined from direct measurements of SEL of individual pass-bys for both conditions. One question arises can the measurements support this values? Performing the mathematical analysis, the following values are obtained:

Table 8- Mathematical analysis

		Sample (N)	Experimental Standard deviation s (x_i)	Reference C
Regardless train categories		51	7 (7,2)	10
Train Categories	Regional	30	3 (3,3)	5
	Inter-city	8	4 (4,0)	5
	High Speed	8	3 (2,9)	5
	Freight	5	5 (5,0)	5

It is easily concluded from the table that the measurements data supports the values suggested by the standard for the parameter C, in both situations.

4.1.2.2 Determination of L_{den} from individual events and determination of the expanded uncertainty

The objective of this measurement was the determination of a long term parameter L_{den}, from individual events. Following strategy defined in point 10.5.2 and equation (D.18) from reference [5], the objective will be to obtain the parameters L_{day}, $L_{evening}$ and L_{night} and L_{den}. The events were stratified into relevant source categories according to the definition previously presented. The next step was to obtain the average of each relevant source category i, $L_{E,i}$ and then calculate the L_{day} for the reference conditions, according to:

$$L_{day} = 10\log\left[\sum_{i=1}^{n} N_{ref,i}.10^{0,1L_{Ei}}\right] - 10\log(T_{ref}) \quad (9)$$

where L_{Ei} is the measured average sound exposure level of trains of category i, n is the number of train categories identified and $N_{ref,i}$ is the number of trains for each category i passing during the reference time and T_{ref} is the reference time (in seconds as the L_{Ei} is integrated in seconds).

At this point, an assumption about the number of trains passing in each period is necessary in order to calculate the other parameters. That information was taken from the timetables available at the Portuguese Railway Company web site, which is the only operator of passenger trains in the country. For freight trains there was no available information so an estimate according to on-site observations was done.

Table 9- Estimation of the yearly number of trains

	Statistics of the yearly number of trains per period of reference					Trains per hour assuming constant volume of traffic
	Regional	Inter-City	High Speed	Freight*	Total	
Day (07:00 – 19:00)	34	11	16	10	71	5,92
Evening (19:00 – 23:00)	8	4	5	4	21	5,25
Night (23:00-07:00)	5	1	1	0	7	0,88

And finally the parameters of L_{day}, $L_{evening}$ and L_{night}, (favourable conditions only) can be calculated in order to obtain the long term estimation for L_{den}.

Table 10 – Final results

L_{day} dB(A)	$L_{evening}$dB(A)	L_{night} dB(A)	L_{den} dB(A)
67,0	66,5	58,7	68,7

The uncertainty budget for the determination of the L_{den} from short-term measurements and calculation, will be:

Table 11- Uncertainty budget for the determination of the L_{den}

Quantity	Estimate (dB(A))	Standard Uncertainty, u_i (dB(A))	Magnitude of sensitivity coefficient, c_i (dB(A))	Uncertainty contribution c_iu_i (dB(A))
L'+ δ_{slm}+ δ_{sou}	L'	u(L') 0,5 ---	$\frac{1}{1-10^{-0,1(L'-L_{res})}}$	3,29 0,50 ----
δ_{met}	0	u_{met}	1	2,00
δ_{loc}	0,0-6,0	u_{loc}	1	0,00
L_{res}+ δ_{res}	L_{res}	u_{res}	$\frac{10^{-0,1(L'-L_{res})}}{1-10^{-0,1(L'-L_{res})}}$	0,25
U (L_{den})				3,88
Expanded uncertainty				7,8
Lden	68.2			

5 Conclusions

The results from the road traffic noise exercises indicate that the magnitude of the uncertainty associated with a short term measurement of LAeq,1h calculated using the procedure presented in the ISO 1996-2:2011 working draft [5] was ± 4,2dB with a confidence level of 95%. This shows excellent agreement with the method presented by Craven [6] for which the expanded uncertainty was ± 4,3dB with a confidence level of 95%. In each case the largest source of uncertainty was associated with the effect of meteorology on propagation.

For railway traffic noise, the uncertainty for the determination of the L_{den} from short-term measurements was ± 7,8dB with a confidence level of 95%. In this case the standard uncertainty associated with the source operation was the largest. The results of the railway traffic noise exercises supported the factors for the standard uncertainty associated with the source operation recommended in the ISO 1996-2:2011 working draft.

Further work should include long term measurements for comparison. The ISO 1996-2:2011 working draft presents an example of an uncertainty estimation for a long term measurement. It was based in 75 efficient 24-hour measurements taken during the stratified periods (day, evening and night) and between four different meteorological classes. The expanded uncertainty associated with that measurement was less than 1dB(A).

The estimation of the uncertainties associated with environmental noise measurements is currently considered to be an important issue. However, probably due to the lack of guidelines for its estimation in standards it is not yet frequently considered. With the presentation of calculation methods and estimation examples in the ISO 1996-2:2011 working draft, in future the uncertainty estimation will need to be considered when reporting measurements. Knowledge of the uncertainty associated with a certain measurement and or calculation will allow more reasoned decision making. It is suggested that further guidelines and worked examples would help to promote the implementation of the uncertainty estimation for environmental noise measurements.

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