The Development of ISO/PAS 1996-3 on Impulsive Sound Prominence

Douglas Manvell [1], Torben Holm Pedersen[2],

[1] DMdB, Charlottenlund, Denmark
douglas.manvell@dmdbsoundadvice.com
[2] SenseLab, FORCE Technology, Hørsholm, Denmark
thp@force.dk

Abstract
Noise with prominent impulsive sound is more annoying than continuous types of noise (without impulses or tones) with the same equivalent sound pressure level. Therefore, an adjustment is added to the measured L_{Aeq} if prominent impulsive sound is present. In ISO 1996, three categories of impulsive sound have been found to correlate best with community response, and adjustments are given for each. The list of sources of impulsive sound for each category is incomplete.
Therefore, ISO is developing a method, ISO PAS 1996-3, based on NORDTEST NT ACOU 112, to objectively measure the prominence of impulsive sound relative to residual sound. The resulting adjustments can be applied directly or may be used to categorize the impulsive sources. It is intended to complement the ISO 1996-2 measurement method for general purpose environmental noise assessment.
This paper describes the background of the method and its development as a Publicly Available Specification.

Keywords: environmental noise, standards, impulses, adjustment to L_{Aeq}.

1 Introduction

Noise with prominent impulsive sound is more annoying than continuous types of noise (without impulses or tones) with the same equivalent sound pressure level. Therefore, an adjustment is added to the measured L_{Aeq} if prominent impulsive sound is present.

ISO 1996-1 2003 [1] defines impulsive sound as sound characterized by brief bursts of sound pressure, and it is noted that the duration of a single impulsive sound is usually less than 1 s. In this and in the current ISO 1996-1 [2], three categories of impulsive sound have been found to correlate best with community response, and adjustments are given for each. The list of sources of impulsive sound for each category is incomplete.

Therefore, ISO is developing a method, ISO 1996-3 [3], based on NORDTEST NT ACOU 112 [4], to objectively measure the prominence of impulsive sound relative to residual sound. The resulting adjustments can be applied directly or may be used to categorize the impulsive sources. It is intended to complement the ISO 1996-2 [5] measurement method for general purpose environmental noise assessment.

2 Background of the Method

2.1 The ISO 1996 standard at the turn of the millennium

During development of the 2003 edition ISO 1996-1 Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment Procedures and the 2007 edition of ISO 1996-2 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels [6], consensus was reached that impulsive noise was best assessed by the classification of sources into one of 3 categories.

In the definition of impulsive sound sources, updated in the 2017 edition of Part 1, it was noted that no mathematical descriptor exists to unequivocally define the presence of impulsive sound, or to separate impulsive sounds into the 3 categories identified. Thus, the sources of sound listed are used to define impulsive sound sources as shown in Table 1.

Table 1 – definition of impulsive sound sources in ISO 1996-1.

Category	Description	Examples
high-energy impulsive sound source	Explosive source where the equivalent mass of TNT exceeds 50 g, or sources with comparable characteristics and degree of intrusiveness Sources of sonic booms include such items as aircraft, rockets, artillery projectiles, armour projectiles, and other similar sources. Does not include the short duration sonic booms generated by small arms fire and other similar sources	Quarry and mining explosions, sonic booms, demolition, or industrial processes that use high explosives, explosive industrial circuit breakers, and military ordnance (e.g. armour, artillery, mortar fire, bombs, explosive ignition of rockets, and missiles)
highly impulsive sound source	Source with highly impulsive characteristics and a high degree of intrusiveness	Small arms fire, hammering on metal or wood, nail guns, drop-hammer, pile driver, drop forging, punch presses, pneumatic hammering, pavement breaking, or metal impacts in rail-yard shunting operations
regular impulsive sound source	Impulsive sound source that is neither highly impulsive nor high-energy impulsive sound source Includes sounds that are sometimes described as impulsive, but are not normally judged to be as intrusive as highly impulsive sounds	Slamming of car door, outdoor ball games, such as football (soccer) or basketball, and church bells. Very fast pass-bys of low-flying military aircraft can also fall into this category

Adjustments to the L_{Aeq} are 5 or 12 dB for regular and highly impulsive sound sources, respectively. For high-energy impulsive sounds, the adjustment depends on the C-weighted sound exposure level L_{EC} level.

Adjustments for impulsive source character are only applied when those sources are audible at the receiver location. When the sound cannot be separated from the sound from other sources, or the impulses are so infrequent that they do not affect the result, then the adjustment is ignored. The minimum rate at which the adjustment is applied is deferred to responsible authorities but typical minimum rates are given as one event every few seconds or every few minutes.

ISO 1996 proposes that, when the bandwidth-adjusted signal-to-noise ratio, D', exceeds 14 dB, the impulse source sound is noticeable in the presences of residual sound [7] and should be assessed. It is important to note that, the standard notes that some countries apply objective prominence tests to assess whether sound sources are regular impulsive.

2.2 National situations differing from ISO 1996

In Germany, an objective impulse adjustment method is described in TA-Lärm [8] and has been used for many years.

In Denmark, the NORDTEST NT 112 method has been used since its publication in 2002. And, in the period leading to the 2003 edition, the NORDTEST method was discussed in the ISO working group but was deemed to have been insufficiently tested to influence the consensus on the methodology, particularly as it just been published at that time.

Nevertheless, in UK, the BS 4142 rating level method [9] was updated to also utilise the NORDTEST objective impulse detection method with to determine the impulse penalty. Subsequently, this was also adopted as a potential assessment method in Australian standard AS1055 [10][4].

2.3 The Needs of ISO

Just after 2000, the ISO working group identified that the standard could be improved on this issue, particularly as the impact of the impulsive noise adjustment are significant and, in several cases, more important than other corrections. One of the main issues was that it was difficult to categorise sources not listed in the standard without an objective method. Examples of such sources include stonemasonry, metal transport cages as used in grocery deliveries to supermarkets, skateboard parks and powered lug wrenches. Douglas Manvell offered to collate issues, state of the art of current knowledge and possible improvements on this topic to form the basis of a qualified review, and the working group investigated what literature existed concerning the human response to various impulsive sound sources: military, construction, industrial, sport, music, helicopters, etc. As a result, several countries in the Working Group supported investigating the NORDTEST objective impulsivity method as an ISO method to determine impulsive sources.

3 The NORDTEST method

The development of the NORDTEST ACOU 112 method started as a research project founded by the Danish Environmental Agency, [11]. The purpose was to develop an objective method for a penalty that was in accordance with the extra annoyance due to the impulses heard. The method should be based on the perceived sound at the receiver position including masking from any continuous noise (including residual sound) irrespective the category of the sound source, although military sound sources was excluded. The hypothesis was, that the annoyance increased with the prominence of the impulses.

The method was developed on basis of the results from listening tests on recordings of impulse sound from real sound sources in continuous background sound. The recordings were sounds with various level differences and onset rates. The method defined an impulse as “the sudden onset of a sound” and the method calculates the prominence P, of the impulses in accordance with the results of the listening tests. A method based on a combination of the psychoacoustic-related measures for level difference (sone ratio: sonebackgr./sonemax.), onset rate (sone ratio/s), and sharpness was tested. Although this was promising, the method based on A-weighted measures was preferred for practical reasons, see Figure 1.

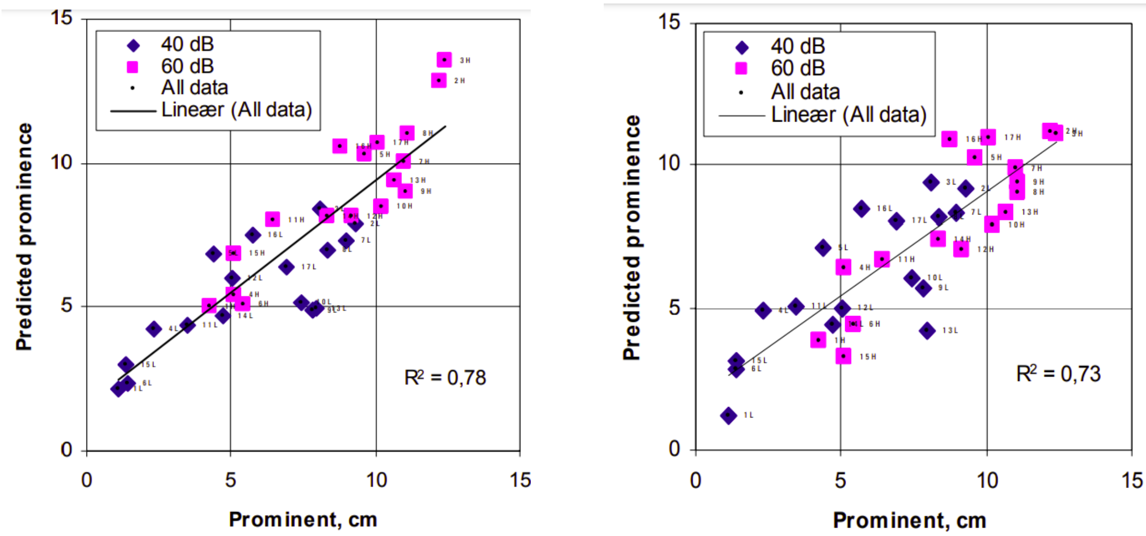

Figure 1. The listeners' judgements of "Prominent" (x-axis) and the prominence predicted from the measuring method (y-axis). The left panel shows the results for psychoacoustic measures based on sone and sharpness. The right panel shows the prominence predicted from the preferred method based on A-weighted measures with time weighing F. From [11].

The objective measuring method is based on the onset rate and level difference for the A-weighted time history of the sound pressure level with time weighting F, see Figure 2

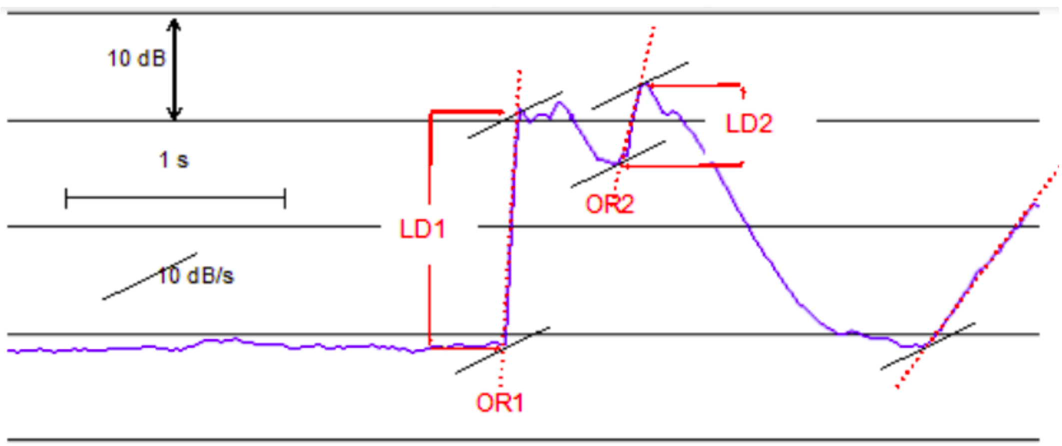

Figure 2. Time history of the A-weighted sound pressure levels with time weighting F (Fast). The figure illustrates the onset ratio (OR) and the level difference (LD) for the two most prominent impulses. Gradients of 10 dB/s are indicated with short line segments. From [4].

The prominence, P, of an impulse is specified as:

$$P = 3*\log(\text{onset rate}/[\text{dB/s}]) + 2*\log(\text{level difference}/[\text{dB}]) \qquad (1)$$

where the "onset rate" in dB/s and the "level difference" in dB are defined more closely in the method.

From the prominence, P, the adjustment for L_{Aeq}, K_I, is defined as:

$$K_I = 1.8 * (P - 5), \text{ for } P > 5, K_I = 0 \text{ for } P \leq 5 \quad (2)$$

The method is intended for use on sources with impulsive characteristics. Examples on use cases, but not limited to these, are: Hammering on metal or wood, nail guns, drop-hammer, pile driver, drop forging, punch presses, pneumatic hammering, powered lug wrenches, compressed air release, pavement breaking, scrap handling, metal impacts in rail-yard shunting operations, slamming of car door, goods delivery, fork lift with rattling forks, outdoor ball games, such as football (soccer) or basketball, skateboard ramps, church bells. Fast and close pass-bys of low-flying military aircraft, trains and road traffic can also fall into this category.

Examples of the prominence and the adjustment for examples of sound sources are shown in Figure 3. The prominence, P (x-axis) and the adjustment K_I, (y-axis) calculated for some examples of sound sources

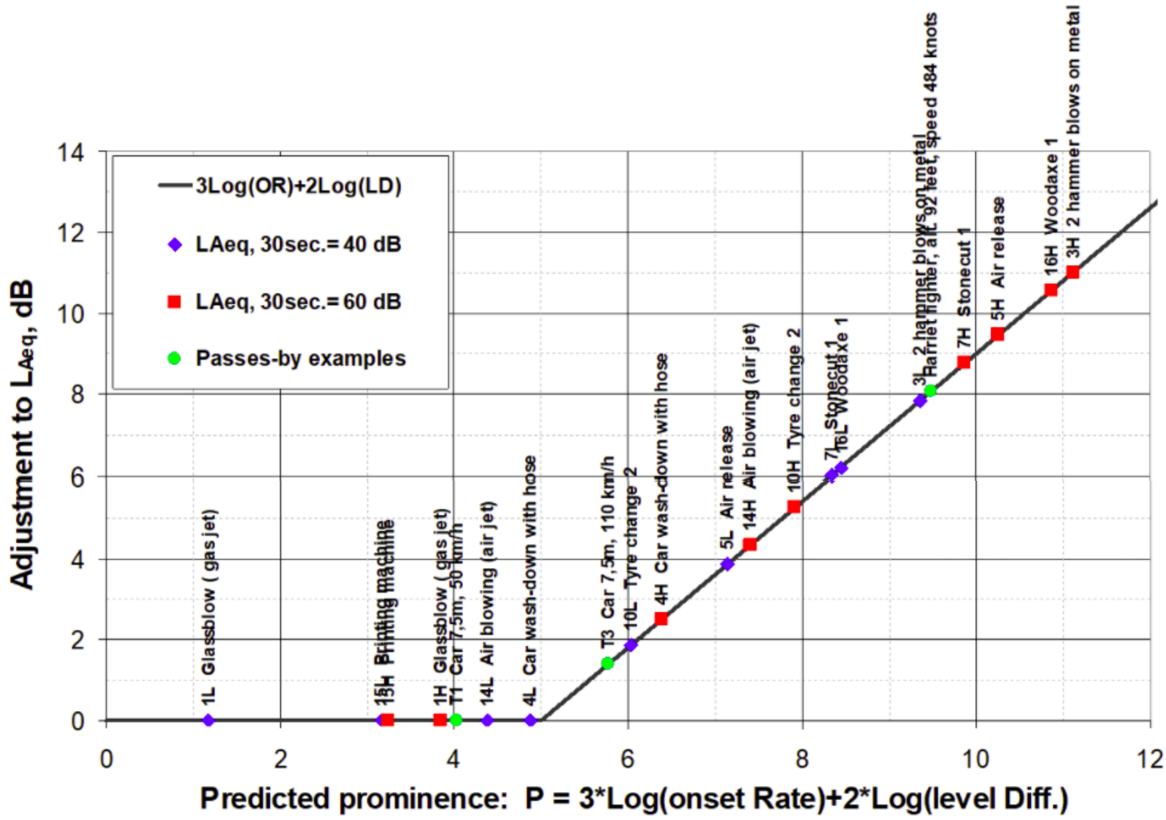

Figure 3. The prominence, P (x-axis) and the adjustment K_I, (y-axis) calculated for some examples of sound sources. From [11].

The method is intended for environmental noise for use in immission points (at neighbours) to determine how prominent the impulse characteristics are perceived within the continuous part of the noise, including the background noise. For such conditions the prominence is normally below 9, leading to adjustments of up to 8 dB. Nearby hammer blows on metal with low background noise, for example, may give penalties of up to 11-12 dB but that is not normal for environmental noise.

The method was further developed and tested in a NORDTEST project which included a Round Robin Test among the four Nordic laboratories that participated in the project, [12]. Among other things, the influence of the sampling interval for the A-weighted sound pressure level with time weighting F was tested. The sampling interval had an effect on the result so a fixed and well-defined sampling interval would have been optimal but, to enable the use of several types of measuring equipment, it was decided that sampling intervals in the range of 10-25 ms could be allowed, with 10 ms preferred for the best accuracy. As a result, the standard deviation of the results on the adjustment K_I in the NORDTEST Round Robin test was 0.5 dB.

In proficiency tests among approximately 30 Danish laboratories approved for noise measurements, objective measurements on impulses according to this method were included in 2003, [13], 2007, [14] and 2017, [15]. The standard deviations on K_I, were 2.0, 0.7, 0.5 and 0.1-0.5 depending on the complexity of the sound samples. Compared with the results from the NORDTEST Round Robin with a standard deviation of 0.5 dB, it can be concluded that the deviation on K_I measured by different laboratories in most cases will be around 0.5 dB. This is many times better than subjective assessments of whether impulse adjustments should be given.

The method is intended for automatic or semi-automatic analysis for periods (e.g. hours) of noise containing impulsive sounds. An example is shown in Figure 4.

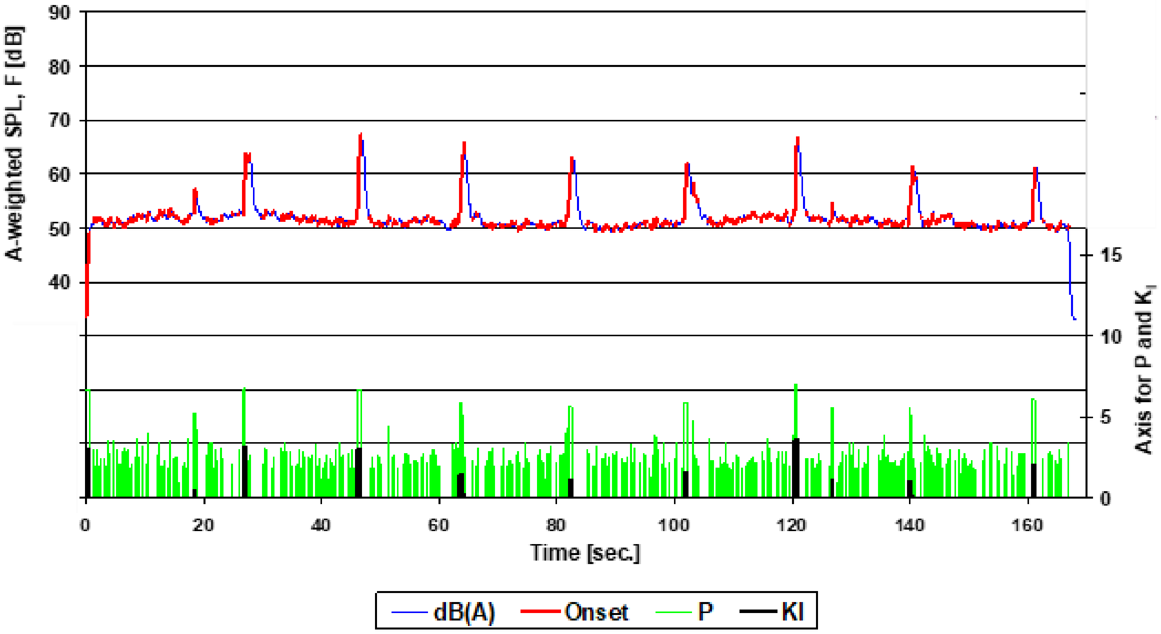

Figure 4. An example on automatic analysis of the impulses in the noise from a scrapyard. The upper blue graph shows the A-weighted sound pressure level with time weighting F, where the onsets are marked with red. The lower graph shows the prominence, P in green, and the adjustments, K_I in black, for the impulses. According to the method the impulse with the highest K_I determines the adjustment in the corresponding 30 minutes period. From [13]

As example of an automatic analysis of the impulses from hundreds of cars passing over bridge expansion joints see [16].

4 Developments in ISO

4.1 Preparation in the ISO Working Group

With the publication of BS 4142: 2014, the ISO working group proposed publishing the NORDTEST method as, for example, a Technical Report to, at least, get more international feedback. Thus, in 2015, the working group agreed to propose a Technical Report on an objective method to determine impulsive sources and therefore to enable categorization of impulsive sound sources for use in ISO 1996. The objective method was to be based on the NORDTEST method with the addition of a short foreword on future research topics, issues and application to ISO 1996. Douglas Manvell was tasked with drafting a New Work Item Proposal which, after review in the working group, would be presented to ISO TC43/SC1 for approval as a new work item. In the proposal, the NORDTEST method was updated to match ISO 1996 procedures and, on request from the ISO working group, to alternatively enable adjustments based on the analysis as opposed to source identification/classification.

4.2 Approval as a New Work Item

As a result of this, in late 2018, Danish Standards (DS) submitted a New Work Item Proposal for a Public Available Specification ISO/PAS 1996-3 "Acoustics — Description, measurement and assessment of environmental noise — Part 3: Objective method for the measurement of prominence of impulsive sounds and for adjustment of L_{Aeq}" allocated to ISO/TC 43/SC 1/WG 45 "Description and measurement of environmental noise (Revision of ISO 1996-series)", with Douglas Manvell as project leader. A Publicly Available Specification is an ISO publication with a relatively short validity after which it must be withdrawn or converted to another ISO document such as a full standard.

The approved scope of work is objectively to categorise sources by determining how prominent the impulse characteristic is perceived at the receiver location through the continuous part of the noise including the background noise. This method for measuring the prominence of impulsive sounds is intended for sources not identified as gunfire or high-energy impulsive sound. It produces adjustments which are intended used to be used to categorise the sources into either regular impulsive or highly impulsive sources and apply the penalty indicated in ISO 1996-1. However, the adjustments may be applied directly.

5 New insight and next steps

5.1 Development of the Standard

During development of the PAS, the impact of the sampling rate used was investigated. It was identified that sampling rates of 10-25 ms did not produce significant differences in results, and thus is permitted. A 100 ms sampling rate, available in a wide range of commercial sound level meters, was also investigated and, on the basis of the differences in some results, is permitted for survey measurements.

The period over which the impulse adjustment is applied, the ”assessment time interval”, was debated and set as default to 30 minutes. However, for assessments with short-duration reference time intervals, shorter assessment time intervals are permitted.

The working group confirmed that the impulse adjustment either be applied by categorizing sources in one of the 3 categories listed in ISO 1996-1, or be used directly as the impulse adjustment, K_I. In addition, the assessment location is defined.

Editorially, the standard has been refined and improved through ensuring that the scope, definitions, terminology, wording and diagrams are clear. The bibliography has also been updated.

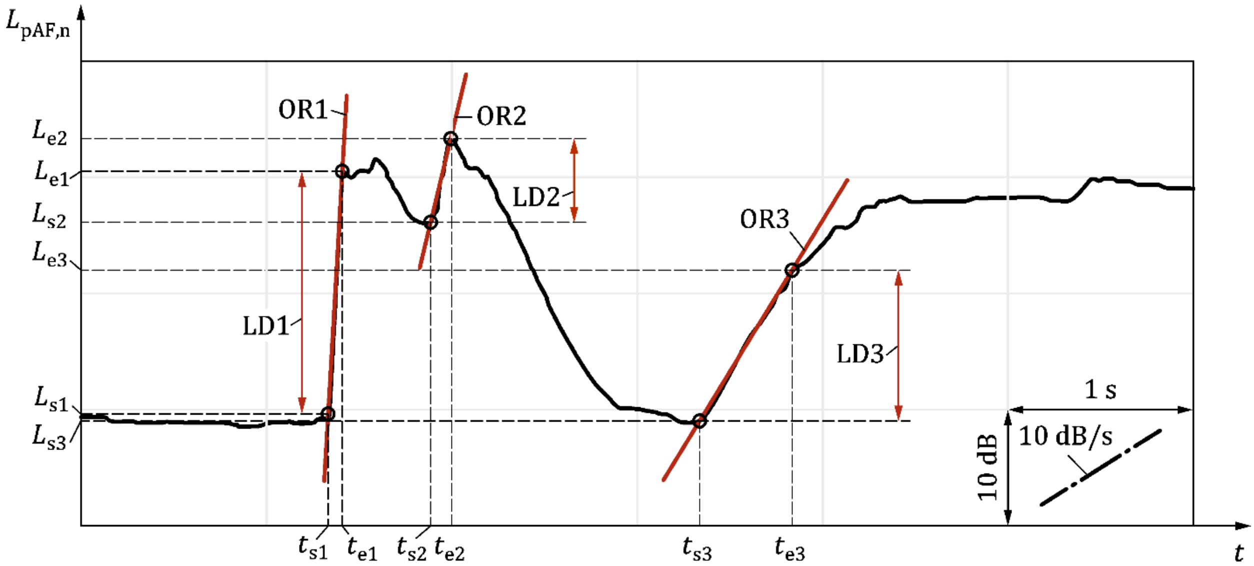

Figure 5. Figure from ISO PAS 1996-3 that shows the time history of the A-weighted sound pressure levels with time weighting F, and illustrates the onset rate (OR) and the level difference (LD) for the three most prominent impulses. It is comparable with Figure 2 in this paper.

To conclude, the working group could confirm that the method was robust enough for publication to thus enable and promote its wider use and evaluation.

5.2 New Insights

Recently a literature study for the Danish Environmental Protection Agency has been made [17]. It is noteworthy that most of the studies found were conducted before 2004. Only the Finnish study mentioned below is of more recent date. Despite a thorough literature search, no significant sources have been found in the period 2004-2019, which is surprising. The literature found that penalties of up to 8-11 dB are representative of the extra annoyance that the impulses give rise to. This is in line with the adjustments the objective measuring method normally operates with.

In a recent Finnish study, [18], the annoyance of repetitive artificial impulses within background sound was compared to the annoyance of road traffic noise in a listening test, see Figure . The level difference (named D_L in the figure) and the onset rate (named R_{On}) for the impulses were varied in a systematic manner.

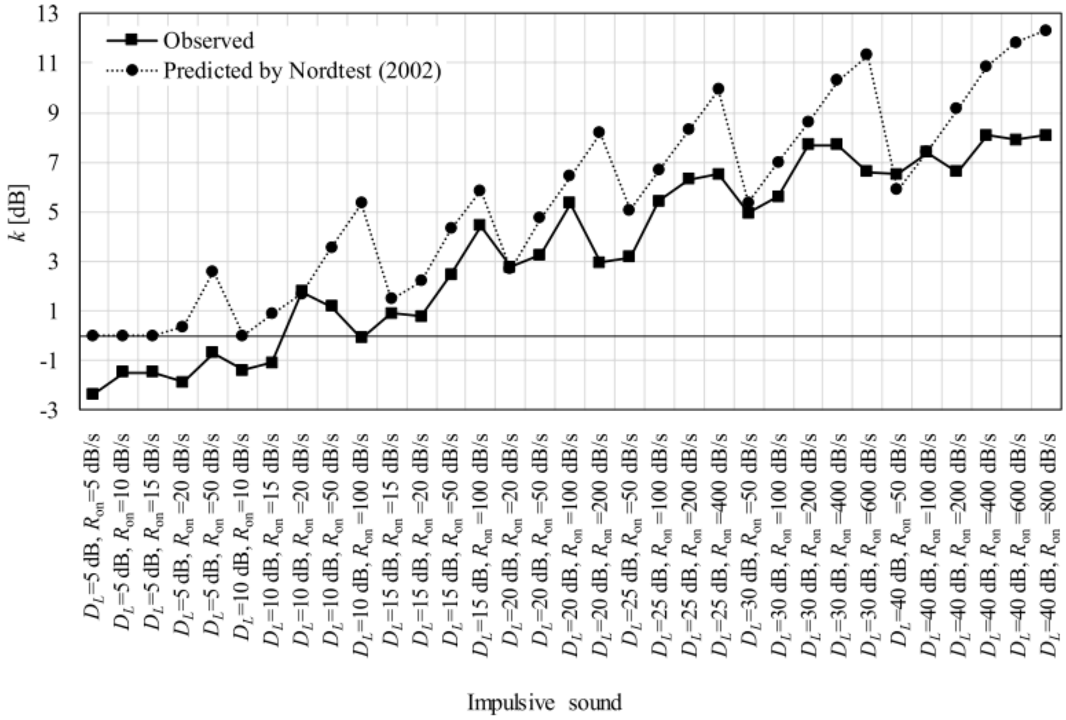

Figure 6. The observed and calculated (with NT ACOU 112) penalties for impulse sounds. Figure from [18].

It is seen that the objective measurement method NT ACOU 112 gives good agreement with the experimental results for slopes up to approximately 100 dB/s. Above this, a saturation effect seems to occur so that, for greater onset rates the method seem to overestimate the size of the adjustment for the artificial sounds used in this experiment. The results from this listening test, may indicate that setting an upper limit of the influence of the onset rate may improve the method (e.g. by limiting or lowering or limiting the second term in Equation 1). But the findings are based on very artificial signals so, as mentioned in the article, listening tests with real life impulses should be performed before any changes are made. When such results are available, a multiple-regression analysis with level difference and onset rates as independent variables should be performed on all available (old and new) listening tests results, and may be used to change and improve the method. Until then we don't have a solid background to impose changes.

Further research along these lines (annoyance of impulsive noise compared to the annoyance continuous road traffic noise) is recommended.

5.3 Next Steps

The Publicly Available Specification has been voted and commented on in the wider acoustic standardisation community. It was supported and could have been published. However, it was agreed that the working group review all comments prior to final confirmation and publication. Publication is targeted for the start of 2022. It will be reviewed 3 years after publication, after which a decision on its future will be taken. Researchers, cognizant authorities and experienced practitioners are encouraged to use this standard in the coming years to ensure that this review is based on a broad and solid foundation.

6 Conclusions

The development of this ISO PAS 1996-3 method to objectively measure the prominence of impulsive sound relative to residual sound enables noise with prominent impulsive sound to be better assessed through a supplementary objective method that is based on methodology used in several countries over quite a few years. It enables more sources of impulsive sound to be correctly categorised.

The resulting adjustments can be applied directly or may be used to categorize the impulsive sources. It is intended to complement the ISO 1996-2 measurement method for general purpose environmental noise assessment. It is hoped that it will be widely used so that, when the ISO Publicly Available Specification is reviewed, the decision can have a wide and solid foundation.

References

[1] ISO 1996-1 2003, Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment Procedures, Switzerland, 2003

[2] ISO 1996-1 2016, Acoustics — Description, measurement and assessment of environmental noise — Part 1: Basic quantities and assessment Procedures, Switzerland, 2016

[3] ISO DPAS 1996-3 2021, Acoustics — Description, measurement and assessment of environmental noise — Part 3: Objective method for the measurement of prominence of impulsive sounds and for adjustment of L_{Aeq}, Switzerland, 2021

[4] NORDTEST NT ACOU 112, 2002: Impulsive noise - Objective method for the measurement of prominence of impulsive sounds and for adjustment of L_{Aeq}". http://www.nordtest.info/wp/2002/05/01/acoustics-prominence-of-impulsive-sounds-and-for-adjustment-of-laeq-nt-acou-112/

[5] ISO 1996-2 2017, ISO 1996-2 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels, Switzerland, 2017

[6] ISO 1996-2 2007, ISO 1996-2 Acoustics – Description, measurement and assessment of environmental noise – Part 2: Determination of environmental noise levels, Switzerland, 2007

[7] Schultz T.J., Synthesis of social surveys on noise annoyance. J. Acoust. Soc. Am. 1978, 64 (2) pp. 337–405

[8] Sechste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz (Technische Anleitung zum Schutz gegen Lärm – TA Lärm), Technical Instructions for Protection against Noise - TA Lärm, http://www.verwaltungsvorschriften-im-internet.de/bsvwvbund_26081998_IG19980826.htm (English) , Germany, 1998

[9] BS 4142:2014+A1:2019, Methods for rating and assessing industrial and commercial sound, UK 2014 and 2019

[10] AS1055, Acoustics - Description and Measurement of Environmental Noise - General Procedures, Australia, 2018

[11] Pedersen, T. H., Impulsstøj, Objektiv målemetode for impulsers tydelighed og for tildeling af impulstillæg. (Impulsive Noise. An Objective Measuring Method for the Prominence of Impulsive Sounds and for the Adjustment of LAeq), Arbejdsrapport fra Miljøstyrelsen Nr. 1, 2001 (Report in Danish with expanded English summary) https://www2.mst.dk/Udgiv/publikationer/2001/87-7944-375-3/html/default.htm

[12] Andersson, H. et al. Round Robin Test of an objective measuring method for the de-termination of the prominence of impulsive sounds and for the impulse adjustment of LAeq, SP Report 2000:30, Acoustics, Borås 2000. Sweden. http://www.diva-portal.org/smash/get/diva2:962160/FULLTEXT01.pdf

[13] Enggaard, A. L., Kragh, J. og Pedersen, T. H. 14. sammenlignende støjmåling. (14th Proficiency Test – in Danish), Miljøstyrelsens Referencelaboratorium for Støjmålinger, Rapport no. 17, 2003

[14] Laursen, J.E., Pedersen, T.H. 16. sammenlignende støjmåling. Miljøstyrelsens Referencelaboratorium for Støjmålinger, 2007. https://referencelaboratoriet.dk/wp-content/uploads/2010/07/Rapport-19-16-sml-stojmaaling.pdf

[15] Laursen, J.E., Backalarz, C. 23. sammenlignende støjmåling. Miljøstyrelsens Referencelaboratorium for Støjmålinger, 2017. https://referencelaboratoriet.dk/wp-content/uploads/2018/05/2017_Referencelaboratoriet_Rapport_nr_30_23_sammenlignende-stojmaaling.pdf

[16] Pedersen, T. H. Finne, P., Hansen M. B., Prominence of impulses from road bridge expansion joints. Euronoise 2018, Greece

[17] Pedersen, T. H. Vurdering af ekstra gene fra impulsstøj – et litteraturstudie (Assessment of the extra annoyance from impulsive noise – a litterature study. In Danish with an English summary). 2021. https://referencelaboratoriet.dk/wp-content/uploads/2021/04/120-34131-Miljoestyrelsen-Vurdering-af-ekstra-gene-fra-impulsstoej-TC-101712.pdf

[18] Rajala, V. and Hongisto. V., "Annoyance penalty of impulsive noise – The effect of impulse onset," Build. Environ., vol. 168, no. 106539, 2020.