Proceedings of the Institute of Acoustics

A REVIEW OF METHODS FOR QUANTIFYING ACOUSTIC FEATURES IN ENVIRONMENTAL NOISE

Bernard F Berry, Director, Berry Environmental Ltd. bernard@bel-acoustics.co.uk
Nicole Porter, Independent Consultant. nicoleporter1@btopenworld.com

1 INTRODUCTION- THE CONTEXT, AND NEED FOR THIS REVIEW

The Department of Trade and Industry, through its National Measurement System Directorate, has been funding a major research project on Environmental Noise. The aims were to improve the quality and face validity of environmental noise measurements, and to contribute to the improvement of British, and International [ISO] Standards on environmental noise. The project had three related aspects, with a separate work package being organized for each aspect:

- A critical review and inter-comparison of methods of quantifying acoustic features in environmental noise, such as tones and impulses – Work Package 1.
- Identifying and quantifying sources of uncertainty in environmental noise measurements. – Work Package 2. Note [1]
- Publishing practical guidance on minimizing such uncertainties - Work Package 3.[1]

There exist a plethora of objective methods for detecting features in noise and/or their character correction, the latter being related to the supposed subjective annoyance likely to result from the feature. See Porter, Flindell and Berry [1]. Indeed, there has been no robust inter-comparison of the various objective methods, either in terms of their relative effectiveness or in terms of their ease of implementation.

A previous UK Department of the Environment-funded project, carried out at the National Physical Laboratory, NPL, involved subjective listening tests on the judged annoyance of specific types of industrial noise. This explored the effect of two acoustic features - impulsivity and tonality - on subjective annoyance, and the performance of objective rating and assessment methods [2,3]. An outcome was the confirmation of the uncertainties relating to the identification and assessment of acoustic features. In the conclusions we recommended that future work should develop better descriptors for the identification and quantification of the physical magnitudes of various features. That work was concluded over 10 years ago, and there has been more development of the methods since.

The ultimate aim of identifying features is to provide an accurate and comprehensive description of the noise that is meaningful in terms of the subjective characteristics it represents. However, there are not a great number of published examples where the results of subjective experiments have been used to validate methods of quantifying features. A better approach, which we have adopted, is to concentrate first on deriving objective methods to detect the *presence* of audible features, rather than attempting to determine a formal relationship between the level of a feature and increased subjective response. However during later phases of the project, we did review intercomparisons of methods which involved data in terms of annoyance, subjective penalties etc.

[1] Work Packages 2 and 3 are the subject of another paper at the Conference. A J Bullmore, J Adcock, I H Flindell, and C English. 2005. "A balanced approach to managing uncertainty in environmental sound measurements". Proceedings of IoA Autumn Conference 2005.

giving a brief description of the method, an explanation of the choice of descriptor, together with some brief information on the extent of real world testing and initial comments on the practicality of their implementation.

We will now outline progress in the final stages of the project.

4 FINAL STAGES OF THE PROJECT

4.1 Evaluating the extent of real world testing

We have reviewed previous research on the intercomparison or testing of tonal and impulsive classification methods and developed tables which sum up the main points of previous research, either comparing methods and/or testing the objective methods against subjective response. The tables include details on the tester, methods tested, number of subjects and general comments on the tests and key outcomes. This previous research and related references are described in considerable detail in project reports which will be available on the DTI website www.dti.gov.uk/nms. The main results are outlined below which include a summary of the shortcomings of a group of methods.

Tonal character

The most tested methods are within the group of methods based on tone-to-noise ratio, prominence ratio (TNR, PR and DIN). These methods have been tested on both artificial and real environmental test sounds with between 190 and 215 test subjects. Shortcomings of these methods have been related to the perceived tonality of two-tone complexes, and the overestimation of low frequency tonal sounds. The DIN standard 2002 appears to perform better than the TNR and PR methods, thought to be due to the introduction of the masking index function in the DIN 2002 standard. Research findings also suggested that trackable non-stationary behaviour of frequency modulated tones leads to difficulties when using tonal metrics that are derived from estimated spectra. The methods are found not to be adequate for time varying tones for which an alternative model has been proposed, the Pitch Model, which is suggested to perform better for these types of sounds. The need for a frequency correction, modifications for the criteria of prominence, the handling of tonal harmonics for PR and TNR have been recognised and, in 2002, modifications have been proposed to overcome these. However, it is notable that despite much "within group" testing and external review, no single method has been recommended at this time for rating the prominence of tonal character of sounds.

The Joint Nordic Method presents a method for assessing the audibility of tones in noise. It has been widely tested on both artificial and environmental sounds. It appears to be the most adopted method in Europe for assessing the audibility of tones in noise. In particular variations of this method have been used for wind turbine noise. It is included in the draft ISO standard ISO 1996 'Description and measurement of environmental noise', Part 2, Annex C. It has identified shortcomings in relation to non-stationary (time varying) signals. Additionally, research findings also suggested that trackable non-stationary behaviour of frequency modulated tones leads to difficulties when using tonal metrics that are derived from estimated spectra.

The ISVR method is still really in a research phase at present, and has only had very limited testing in the laboratory using artificial sounds. There are a number of uncertainties, including dealing with two or more tone complexes, non-stationary or non-broadband background noise and the effects of modulation. Although the method shows real promise, more development may be required before it can be recommended for implementation today.

The PR, TNR, JNM and ISVR methods all relate to prominence of tones in noise rather than perceived tonality, such as the Aures method. The Aures method has been tested on over 20 artificial sounds. Although these experiments were specifically aimed at finding solutions to

implementation for each of the selected methods, bringing together both the information on the commercial implementation, e-mail inquiries and the responses on 'research' implementations.

For tones, it seemed that examples of practical implementation are available for nearly all the listed methods. However, many of these are research implementations, noted from the various publications reviewed, rather than commercially available implementations. For impulses, full implementations are less available, in comparison to the situation for tones.

For both tonal and impulsive methods, there are many cases where methods can be implemented by post-processing and current instruments are designed in such a way that post-processing can be used to implement almost any method. However such a situation means that there is a lack of standardisation in exact details of how methods are implemented, leading to greater variability in measured values.

4.3 Objective comparison of methods

It became clear during the later stages of this project that the topic was in a constant state of evolution, and that we could provide only a "snapshot in time". When we examined, in detail, the nature and scale of the research effort which had gone into the testing of various methods, it was clear that we could not expect, with our resources, to apply further meaningful testing, nor to refine any methods but merely document and comment on progress.

There are several "levels" of intercomparison that could be envisaged. The most complex of these would require a wide range of noise samples to be evaluated on a subjective basis by a large panel of listeners and for the same noise samples to be assessed by various objective methods. It was felt that further work on intercomparisons should be focused on a small-scale intercomparison to get some information on practicality and the most suitable 'purposes'/ applications. The final stage of the project therefore adopted this approach.

We decided to choose noise samples, which had already been analysed by other researchers, both subjectively and objectively. We then aimed to carry out additional objective analysis of the same noises and to comment on the findings.

Tones

Although we intended to include a new intercomparison using the Joint Nordic Method for tonal noise using specifically tailored instrumentation options, this initially proved problematic due to the unavailability of suitable equipment at the time of the work. Due to time constraints, it was only possible to carry this work at a late stage.

In terms of implementation, we have found that tonal analysis using instrumentation with specifically included tonal options may in practice be more difficult than one would expect, as one would have to have a dedicated instrument readily available. These instruments can be fairly costly and do not appear to be held by the average environmental officer or consultant. Post-processing may be the more common option available to all but is more time and labour intensive. Further conclusions may have been possible if we had managed to complete this analysis earlier.

For the limited analysis that was completed, we found that the Draft ISO 1996-2 Annex C method was not superior to two of the objective methods tested by Daniel et al, namely E DIN 45681 2002, ANSI S1.13, but was similar to (and even slightly better than) ANSI S1.13 PR, based on the regression fit.

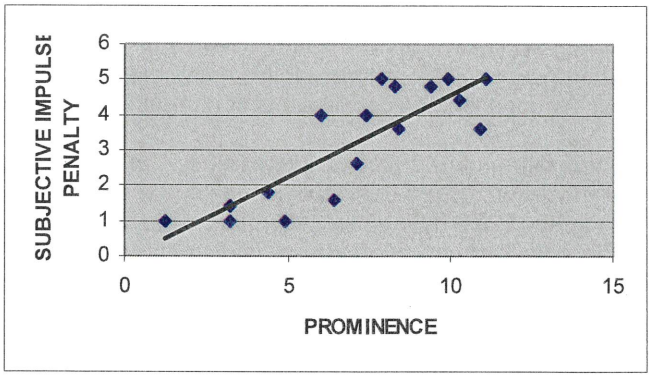

Figure 2. Subjective Impulse Penalty, on a scale of 0 to 5dB, against objective Prominence: R^2= 0.713

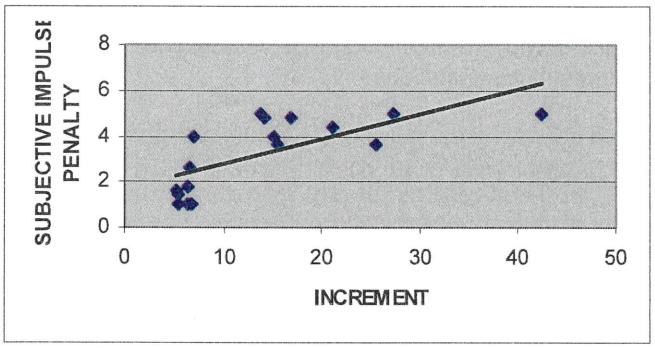

Figure 3. Subjective Impulse Penalty and Increment R^2= 0.501

This reflects the fact, recently indicated by Torben Holm Pedersen of Delta, in a Personal Communication by email, that the NPL Increment method formed the basis for development of the Prominence method, but the method was extended to include the use of the standardised F time-weighting, in order to provide a better psychoacoustic element than $LAeq_{10ms}$.

Towards the end of the project, we were awaiting the outcome of more recent work at Delta in Denmark, in which new software for their noise analysis system Noiselab, [see http://www.delta.dk/noiseLAB/] has been developed to include "automatic" classification of impulses by the Prominence method – and has then be used by them to re-analyse the same set of signals used in previous studies. It would be interesting to see if this particular new implementation of the Prominence method produces significant numerical differences in the values associated with the noises discussed above. However it is unlikely that such differences would be sufficient to have any impact on the comparison of the objective values with subjective data – and hence our conclusions on this topic.

5 SUMMARY AND RECOMMENDATIONS

The project's overall aim is to improve the quality and face validity of environmental noise measurements in the UK. The project had three related aspects, with a separate work package being organized for each aspect. We have met the original aims of the project in critically reviewing and comparing methods of quantifying acoustic features in environmental noise.

Also, since formal completion of the project there have been relevant developments arising from the Plenary Meeting of ISO Technical Committee 43 "Acoustics" / Sub-Committee 1 "Noise", in Canada in June 2005. In this Plenary meeting, a formal Resolution was adopted to register a new Preliminary Work Item PWI, on the work programme of ISO TC43/SC1/Working Group 45, the Working Group which deals with Revision of ISO1996. This PWI has the title - *"Acoustics - Determination of tonal components of noise and determination of a tone adjustment for the assessment of noise immissions".* UK representatives on WG45, namely the authors and Dr Flindell, will watch developments closely.

Details will be given at the Conference of the website on which the full project Report can be found.

6 ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contribution of the other members of the consortium involved in this DTI NMS project – Dr Andrew Bullmore and Justin Adcock of Hoare Lea Acoustics, Dr Ian Flindell of Ian Flindell Associates, and Colin English of the English Cogger Partnership. We also wish to acknowledge the invaluable help provided by all those who responded to our requests for information during the email consultation process, and those who contributed to the survey of commercial implementations of methods. We would particularly like to thank Torben Holm Pedersen of DELTA, Doug Manvell of B&K Denmark, Prof. Dr-Ing. Hugo Fastl of the Technical University of Munich, Ian Campbell of Campbell Associates, UK, Dr Peter Daniel previously of Cortex (now at B&K), Dr Giovanni Brambilla of the Istituto di Acustica IDAC in Rome, and Norman Bolton of NMSD, DTI. The financial support of the UK's Department of Trade and Industry is also acknowledged.

7 REFERENCES

A large number of additional technical references will be found in detailed Reports on the project website – Details of the website will be given at the Conference, or email bernard@bel-acoustics.co.uk .

1. N. D. Porter, I. H. Flindell, and B. F. Berry. 1993. An acoustic feature model for the assessment of environmental noise. Proc. Inst. Acoustics, 1993, 15, Part 3, 1015-1024.

2. N. D. Porter and B. F. Berry. 1993. Subjective effects and objective assessment of combined tonal and impulsive noise. Proc. 6th International Congress of Noise as a Public Health Problem, Nice, 1993, 2, 597-601.

3. B. F. Berry and N.D. Porter, 1994. The evaluation of acoustic features in industrial noise. Proceedings of Internoise 94, Yokohama, Japan, 1994, pp 803-8

4. B. F. Berry and N. D. Porter. 2004. A critical review and inter-comparison of methods for quantifying tonal and impulsive features in environmental noise. Proceedings of Internoise 2004. Prague. Paper 389. CDROM.

NOTE. The present paper is an update of two earlier 2005 papers.

a. *A review of methods for quantifying tonal and impulsive features in environmental noise.* Proceedings of Internoise 2005. Rio de Janeiro. CDROM. Paper 1811
b. *Is it a Tone? Is it an Impulse? Am I certain, or uncertain? - A review of methods for quantifying acoustic features in environmental noise.* Proceedings of INCE Europe Symposium on Managing uncertainties in noise measurement and prediction. Le Mans. CDROM