# New Zealand Acoustics

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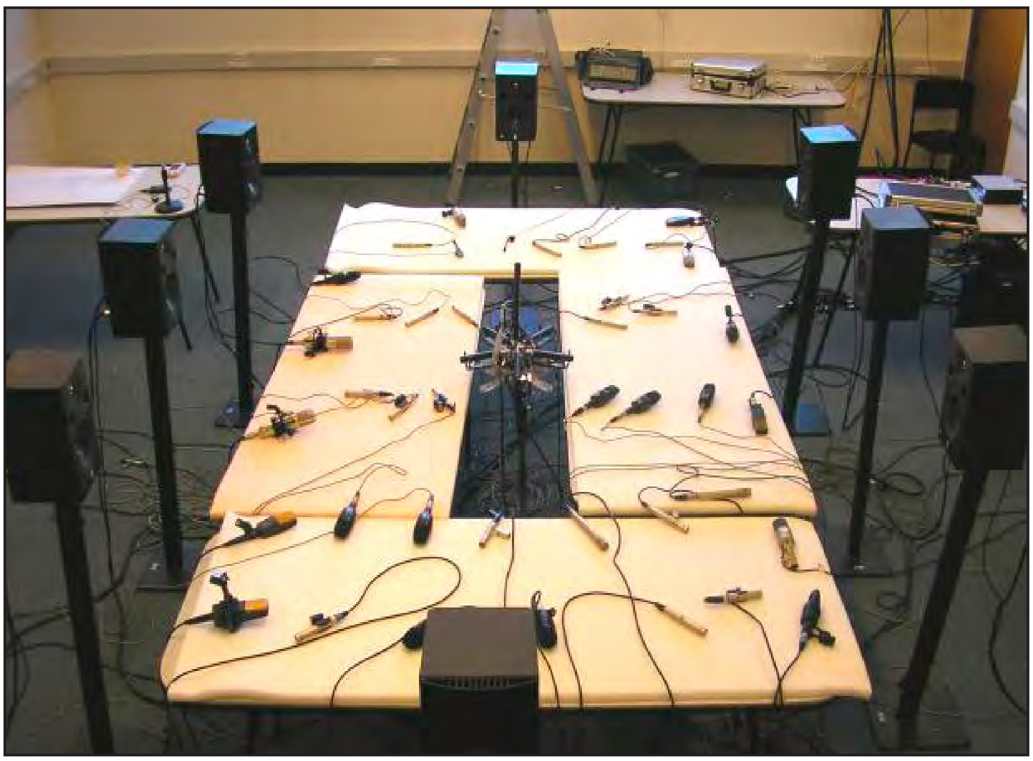

Environmental Monitoring using Arbitrary Microphone Arrays

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# New Zealand Acoustics

Volume 24, 2011 4th Quarter




## Features



## Regulars



*Cover Photo: Layout for simulating people having conversations around an audio/video conference table.*

*Source: Wyatt Page, 2010*


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*Contributions to the Journal are encouraged, and may be sent directly to the Editor either by email, or by post c/o the Acoustical Society of New Zealand Incorporated, PO Box 1181, Auckland.*

# From the President and Editor

## From the President

Dear Members,

As I write this piece for our Summer edition, Christmas is rapidly bearing down upon us with the unrelenting speed of a runaway train. As per usual there are deadlines to meet, presents for friends and family to wrap (and post – I think I may still have time...), deadlines to meet, festive drinks and nibbles to be had, and did I mention deadlines to meet?

Firstly, I should not really be surprised, this seems to happen every year, everything – both work related and otherwise – squashes up in a mad rush towards the day we break from work for the much-anticipated long weekend. You'd think by now I'd be accustomed to it, but it always surprises me how crazy it all seems to become.

Secondly, I should also realise by now that irrespective of how well I plan my time – again, both work related and otherwise – a glitch or three always manage to find their way through, to be dealt with NOW.

This year I really tried to organise myself to have a "clear run" into the break, arranging all manner of things well before their required or allotted time, but still I find myself a little ... I think Bilbo Baggins phrases it nicely ... "Why, I feel all thin, sort of stretched, if you know what I mean: like butter that has been scraped over too much bread."

Anyway, I should stop sounding like I'm complaining, as I think a bit of a stretch brings out not only the worst but also the best in people, it really is lovely to know that people are trying to give their best even when they are pressed.

Thanks to everyone who has stood by my back in the last month or so!

Besides...by the time this goes to print, Christmas and New Year will be a


### Publication Dates and Deadlines

New Zealand Acoustics is published quarterly in March, June, September, and December.

The Deadline for material for inclusion in the journal is 1st of each publication month, although long articles should ideally be received at least 2 weeks prior to this.

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distant memory, and you will wonder why I am still going on about it!

And back to matters acoustic. Back in our Spring magazine, we advised that the Society's Committee had received 2 applications for Affiliate grade and 7 applications for Member grade to the then-newly-instigated Membership regime.

Since then, a further 23 applications have been received and processed, and a further 6 are in the pipeline. I encourage those of you who have not formalized their application documentation to do so!

Best regards to all until the next edition...

*Rachel Foster*

## Editor's Ramble

Thanks for looking through the 4th and final issue of NZ Acoustics for 2011, I know that it hasn't been very long since our last issue, but I have tried to get this one published before the holiday season.

This time we have four interesting articles; the first is a study from Massey University which is investigating the use of augmented audio reality, allowing a participant to interactively change an audio environment, such as a game or meeting, using microphone array processing.

The article includes layouts for simulating a group of people having a discussion around a conference table (I have used one of these images for the cover of this issue), perhaps we could replace real meetings with these simulations!

The second article is also from Massey and concerns the acoustic environment in childhood centres. As a parent, this is an area in which I have a personal interest. The study includes a small study on the hearing acuity of teachers which shows a an increase in hearing loss in older teaching staff (does this apply to university lecturers too? - Time for another study!).

A third paper in this issue is a study of quiet areas of cities for implementation of a European directive. A number of different methods are tried using the town of Pisa in Italy as an example of small city (a quick tip for visitors to Tuscany, the pizza is much better in Florence!).

As usual this issue includes a few small snippets from recent acoustic news stories and of course an acoustically-themed crossword.

Following this, I have included a report from the president of the ICA (International Commission for Acoustics), which provides a status update for the organisation and a few details about future plans. Information about the next conference in Montreal also appears later in this issue.

The first announcement for InterNoise 2012 in New York has also now been issued and you can find further information in our Upcoming Events section on page 36.

The final paper in this issue is about models for sound transmissions through foam-cored panels. These lightweight products are commonly used in the building industry, but they have some sound transmission performance problems for which modelling is needed.

The end of year is often a time of reflection and I have spend some time this week looking back over the last four issues of NZ Acoustics. I can clearly see a number of glaring errors and omissions in early editions, but I now feel much more confident about the process of editing; it certainly took less time for the most recent issues compared to the first one (which took me 80 hours to create).

Next year I hope to have more original articles appear in these pages and I would like to make a few other cosmetic changes, such as a move to a two-column format for papers. As always, I welcome your feedback!

Thanks to everyone who has helped put the journal this year, particularly Grant and Stuart.

All the best for a happy and healthy 2012!

*John Cater*

# Environmental Monitoring Using Arbitrary Microphone Arrays

**Wyatt Page[1], Peter Driessen[2], Pranav Sakulkar[3] and Farook Sattar[4]**

[1]Institute of Food Nutrition and Human Health, Massey University, New Zealand

[2]School of Engineering & Advanced Technology, Massey University, New Zealand

[3]Department of Electrical Engineering, Indian Institute of Technology, Kanpu, India

[4]Department Of Computer System & Technology, University of Malaysia, Kuala Lumpur, Malaysia

*A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland*

## Abstract

Augmented audio reality (AAR) is a mixture of virtual reality and the natural environment. AAR enhances the acoustics of a real world environment with additional audio information. A hearing aid is a simple example of AAR. We describe an experiment in an indoor environment with up to 16 simultaneous voices (such as in a crowded room) and up to 48 microphones in arbitrary configurations. We develop array signal processing algorithms to train the system, and separate, localize, track, enhance and zoom in on the voices. Effective audio zoom algorithms and natural gesture control will be useful in many contexts in of themselves. Their combination will enable a "super" hearing aid which can be applied to restore impaired hearing, guide visually impaired people, as well as enhance natural hearing. The longer-term objective is to develop algorithms to control the location on which the array is focused using head and eye gestures. The listener can simply look at the location from where s/he wants to hear the audio, thus controlling the audio zoom via head and eye gestures.

## Introduction

In this paper we report on the early phases of building a system using microphone arrays of arbitrary geometry to zoom in on desired audio in a noisy environment. Ultimately a listener will be able to simply look at the location from where s/he wants to hear the audio, controlling the audio zoom via head and eye gestures.

The microphone arrays may be a permanent part of a venue, embedded in the walls and ceiling. Or using low cost wireless devices, deployed ad-hoc at the time of use (e.g. stuck to the walls and ceiling with removable adhesive).

Applications of this new audio zoom system include a "super" hearing aid for people in a crowded noisy environment. Such a hearing aid will have performance far exceeding any standard hearing aid with microphones near the ears. Audio zoom may be very useful for the film industry, to capture better quality audio during on-location filming, and reduce the amount of rerecording and post-production required. It may also be useful for the computer games industry where zooming on natural sounds may be desired as part of the game-play. Audio zoom will be a very useful research tool for studying bird communications, providing detailed spatial information on territorial birdsong, which may help decipher the song function.

## Background

Augmented audio reality (AAR) [1][2][3] is a mixture of virtual reality and the natural environment. AAR enhances the acoustics of a real world environment with additional audio information. A hearing aid is a simple example of an AAR system. AAR is a subset of Augmented Reality (AR), but in practice AR systems are focused on visual augmentation with little or no emphasis on any auditory elements. AR is part of the wider mixed reality continuum where the aim is to present the real and virtual elements in a way that they are perceived as one.

One of the most commonly quoted, commercially successful implementations of an AAR system are the Audio Guides such as the Sennheiser guidePORT (www.guideport.com). Although these audio guides typically include noise cancelling technology, they are not really an AAR system but simply location aware audio.

Härmä et al [2] describe an augmented audio environment as:

> "The concept of augmented reality audio characterizes techniques where a real sound environment is extended with virtual auditory environments and communication scenarios. An augmented audio environment is produced by superimposing a virtual sound environment onto the psycho-acoustic environment."

### Literature Review

Microphone array signal processing is reviewed in [6][7]. For our application, the source signals are wideband and mostly indoors where there will be significant multi-path effects. A thorough review of such MIMO (multiple-input and multiple-output) systems appears in [8]. Relevant theories include the following: a fast and efficient frequency-domain Blind Source Separation (BSS) method using Independent Component Analysis (ICA) for a convoluted mixture of audio signals [9], frequency domain convoluted blind source separation algorithms based on real room recordings [10], a novel approach to directly recover the location of both microphones and sound sources from time-difference-of-arrival measurements only [11], and a linear closed-form algorithm for source localization from time-differences of arrival (TDoA) [12]. Learning/training methods are also relevant. A microphone array system is trained using signals from a set of positions and trajectories and subsequently recalls the localization information when presented with new input signals [13]. Because of its learning nature this method provides practical advantages in setting up a microphone array, by not requiring favourable room acoustics, careful element positioning or uniformity of sensors. A generative statistical model for speech and noise sources at distinct regions in the soundfield is used in [14], and incremental Bayesian learning is used to track the model parameters over time. A new method for time delay estimation based on the analysis of the cross spectrum between a pair of microphones [15] is also relevant.

A number of the array signal processing methods in the literature make use of, or can benefit from, knowing the location of the microphones in the arrays and the location of the sound sources. This information can be determined from the time difference of-arrival or relative delay between sound sources and microphones. The multiple-measured room impulse response (MMRIR) attempts to capture the MIMO relationships between sound sources and microphones to obtain a more comprehensive representation of the acoustics of a room. For every source-microphone pairing, an impulse response (IR) is measured. The delay from an IR can be used to estimate TDoA for the most direct path while the complete IR captures the multi-path effects, the timing and intensity of the reflections.

There are a range of approaches to measuring room impulse responses [25]. These include sine sweeps and the use of wideband noise. The exponential sine sweep (ESS) approach has evolved over the last decade to become the preferred method for accurate measurement of room IR [26]. However, the wideband noise approach is very useful for non-stationary sound sources and where an estimate of IR is required in near real-time. Kasami sequences are pseudorandom number sequences that can be used to create wideband noise with special correlation properties. A maximal length sequence (m-sequence) has a large autocorrelation at zero lag, with near zero autocorrelation elsewhere, thus enabling the quick determination of the impulse response of a linear time invariant (LTI) system. Maximal length sequences are also the base of sets of sequences with good correlation properties.

The small set of Kasami sequences is one such set that have small off-peak autocorrelations and also small cross correlations between sequences. This property allows accurate determination of time of arrival time of a transmitted sequence, even in the presence of other interfering transmissions. Code for implementing Kasami sequences is available free from MATLAB Central on "The Mathworks" website (www.mathworks.com/matlabcentral).

Some practical applications of the audio zoom will depend upon methods of controlling the location on which the array is focused. The control algorithms and technologies for user tracking are reviewed in [4][5]. We were unable to find good examples of natural transparent zoom control (without external input devices) for visual or audio sensors [22][23][24].

# Problem Formulation

We consider a signal model where the source of interest, i.e. the speaker is in a fixed position relative to the microphone array. The noise environment consists of interference, i.e. surround speakers, and ambient noise. The $i^{th}$ microphone array received, after sampling, a component from the target speaker, $s(n)$, and a sum of noise sources $v_d(n)$, $d = 1 \ldots D$ together with the ambient noise $v(n)$ as

$$x_i(n) = s_i(n) + \sum_{d=1}^{D} v_{di}(n) + v_i(n) \qquad [1]$$

The array data vector received from M point sources, impinging on an $I$-element array in space, at time $n$, can be described by

$$\mathbf{x}(n) = \sum_{m=1}^{M} u_m(n)\mathbf{h}_m + v(n) \qquad [2]$$

Where $v(n)$ is the received uncorrelated noise, $u_m(n)$ is the signal from the mth point source, and the impulse response (i.e. steering vector)

$$\mathbf{h}_m = [\beta_1 e^{j2\pi f\tau_1}\ \beta_2 e^{j2\pi f\tau_2} \cdots \beta_I e^{j2\pi f\tau_I}] \qquad [3]$$

represents the acoustic path (propagation channel) between the mth signal source and the array, where $\beta_i$ is the attenuation and $\tau_i$ is the propagation time delay from point $m$ to the $i^{th}$ array element. The output signal $y(n)$ can be written as

$$y(n) = \mathbf{w}(n)^H \mathbf{x}(n) \qquad [4]$$

where $w(n)$ is the array filter vector, $x(n)$ defines the corresponding input data vector and $H$ denotes the Hermetian transpose. The purpose is to estimate the filters $w(n)$ such that the target signal $s(n)$ is recovered.

## BSS Method Implementation

A fast and efficient blind source separation (BSS) algorithm is implemented in this paper [9]. This frequency domain approach is based on convoluted mixing model, which provides the flexibility to encompass important factors, such as propagation delay as well as multi-path and wideband nature of the sources. The first step of this approach is transforming the data into frequency domain using a block window which can be approximated as:

$$X(k,n) \approx A_k S(k,n) + V(k,n) \qquad [5]$$

where $X(k,n), S(k,n), V(k,n)$ are the DFT (Discrete Fourier Transform) of the sensor, source and noise signal vectors for frequency bin $k$ and time frame index $n$, respectively, and $A_k$ is the mixing matrix of the $k^{th}$ frequency bin.

The next step is to estimate the unmixing matrix by applying the well-known FastICA scheme at each frequency bin. The FastICA is applied iteratively at each frequency bin starting from the lowest frequency to the highest frequency. The FastICA algorithm [28] makes use of an efficient learning rule to maximize the non-Gaussian nature of the projection. It is among the most commonly used algorithms for optimal search of the unmixing matrix **W** that is updated based on a nonlinear contrast function. The optimization techniques like gradient search or Newton optimization are used for updating the contrast function G(**WX**) where **X** is the observed matrix of the mixed source signals. The general form of the gradient search and Newton optimization techniques for updating the unmixing

matrix **W** is given by

$$\mathbf{W}_{n+1} = \mathbf{W}_n + \eta g(\mathbf{W}_n \mathbf{X}) \quad [6]$$

$$\mathbf{W}_{n+1} = \mathbf{W}_n - \eta \frac{g(\mathbf{W}_n \mathbf{X})}{g'(\mathbf{W}_n \mathbf{X})} \quad [7]$$

where $g(\mathbf{WX})$ and $g'(\mathbf{WX})$ are the first and second derivatives of the contrast function and $\eta$ is an adaptation step size. The function g() can be any non-quadratic function which must be chosen to provide efficient updates.

For the iterative estimation of the unmixing matrix, the final solution of the previous unmixing matrix is used as initial value for the FastICA iteration in the current frequency bin. In this way, there has been improvement in the inherent permutation problem based on the assumption that the values of the unmixing matrices for the adjacent frequency bins are changing slowly. In addition, the scaling problem has been solved by using the diagonal terms of the inverse of the estimated unmixing matrix considering that the unmixing matrix has full rank.

**Figure 1. Part of the recording venue showing some of the boundary placed microphones (wall and ceiling). The white circle indicates the surround-sound microphone array.**

**Figure 2. One of the random speaker layouts for simulating people having conversations anywhere in the room.**

## Experimental

As there are no readily available data sets for multi-channel input and output sound in a real venue, we decided to record our own.

### Setup

An empty moderately sized (8m x 5m x 3m) internal room with a carpeted floor and a suspected acoustic ceiling was used as the venue for an experimental recording session. The room has windows at one end and a large whiteboard at the other. We hired a mobile recording studio along with a sound engineer, from Sounds Unlimited (www.soundsunlimited.net.nz). The mobile studio used a Yamaha DM2000 digital production console as the front end for Apple Logic Studio, Digital Audio Workstation (DAW) software running on a Macintosh Pro computer. The setup provided eight discrete output channels and 48 microphone inputs. Eight Yamaha MSP7 active studio monitors from our surround sound laboratory were used as the output speakers. A collection of professional microphones were used to make up the 48 inputs. The microphones were a mixture of both omnidirectional and cardioid directional patterns.

The last seven microphones were in a surround sound microphone array assembly [27] (see figure 1). The array has five microphones (all Sennheiser MKH50) equally spaced around a circle on a single plane and up and down pointing microphones (both Sennheiser MKH60). In contrast to this structured microphone array, the other 41 microphones were placed reasonably randomly around the room, initially on or close to the ceiling and close to the walls of the long axis of the room. Because of their close proximity to the surfaces, they behave approximately as boundary microphones.

### Experiments

A series of experiments were designed and run in the venue. For each experimental setup, images of the microphone and speaker placement were taken so post calibration of their position could be performed. All data from the microphones was recorded at 24 bits resolution and 48 kHz sampling rate. Almost 50 GB of data was recorded from the sessions and this data is available from the authors for other researchers wishing to collaborate with us.

**Table 1. Details of the 11 recordings made, covering the different microphone placement and operational scenarios**

| # | Title | Description |
|---|---|---|
| 1 | Walk | Test conversation – Two males having a conversation while walking around the room; 12 microphones on the walls + 29 on the ceiling + surround array. |
| 2,3 | Conversation 1,2 | Group conversation – Up to 12 people having conversation slowly moving around the room; 12 microphones on the walls + 29 on the ceiling + sur-round array. |
| 4, 5, 6,7 | Random 1,3,4,5 | Simulated group conversation – Up to 16 voices from eight speakers placed randomly around the room; 12 micro-phones on the walls + 29 on the ceiling+ surround array. |
| 8 | Table 1 | Audio conference – Up to 16 voices from eight speakers placed uniformly around the table; 12 microphones on the walls + 29 on the ceiling + sur-round array. |
| 9 | Table 2 | Audio conference – Up to 16 voices from eight speakers placed uniformly around the table; 29 ceiling micro-phones + 12 microphones on the table + surround array. |
| 10 | Table 3 | Audio conference – Up to 16 voices from eight speakers placed uniformly around the table; 41 microphones on the table + surround array. |
| 11 | Delay Test | Measurement of recording system internal delay, input to output. |

We imitated two microphone placement scenarios. The first is where the microphones are embedded in the walls and ceiling and the second scenario is where they are embedded into an audio/video conference table. In both scenarios we also included the discrete surround-sound array for comparison. Three operational scenarios were imitated in the recording sessions. The first involved real people having conversations anywhere in the room. The second one involved simulating people having conversations anywhere in the room and the third involved simulating people having conversations around an audio/video conference table. For the real-people scenario we invited staff and students to have a conversation amongst the jungle of wires and equipment. Up to 12 different voices could be occurring at the same time. For the simulated conversations, a series of podcasts from Radio New Zealand, the Canadian Broadcasting Corporation and National Public Radio (USA), were downloaded from their website. These podcasts were typically of an interactive interview and included both male and female voices. Each podcast was trimmed to 15 minutes long. The simulated conversations were played-back through the eight studio monitor speakers set on stands 1.2 metres high. Up to 16 different voices could be occurring at the same time in this scenario.

For the second operational scenario, the speakers were placed randomly in the room and with random orientations. Some constraints were applied to the randomization to ensure that the speakers were not hard up against a wall while also being orientated into the wall.

For the simulated audio/video conference operational scenarios, the eight speakers where placed around the table in a regular pattern. Table 1 details the 11 recordings made, covering the different scenarios. Most recording sessions lasted around 19 minutes. For the first four minutes of each recording, signals were played-back through the speakers to measure the MMRIR. Linear sine-wave sweeps were followed by exponential sweeps from each of the eight speakers. Lastly, two different small set Kasami sequences at different sampling rates were played-back simultaneously through all eight speakers.

## Results

Initial testing was done using simulated data with two microphones and two sources (loudspeakers). Two configurations were used: For narrow spacing, the microphones were 4 cm apart. The sources were 1.2 metres apart at a distance of 1 metre from the microphones. For wide spacing, both microphones and sources were arranged in a 3 m x 4 m rectangle with the microphone and speakers 4 m apart.

Blind source separation using the frequency domain method of [9] with two male voices as sources was effective with a two-ray impulse response (direct path plus one reflection), provided that the microphone separation was no more than about 4 cm (half wavelength at 4,250 Hz). The permutation ambiguity problem inherent in ICA technique influences the misalignments for larger separation as frequencies become higher.

Non-blind source separation with the knowledge of IR of the room was tested. As the length of speech signal is not fixed, we cannot perform inverse filtering on the whole signal at the same time. So the signals were windowed and inverse filtering was applied in the frequency domain using STFT (short-time Fourier transform) the and results were recorded for the robustness with changes in parameters.

Figure 5 shows the plot of SIR (Signal Interference Ratio) improvement versus variation in reflection coefficient for wide separation and figure 6 for the narrow separation case. The SIR improvement is better for the narrow separation case and more robust to the changes in reflection coefficient of the wall. This shows that for narrow spacing, we can work with only geometrical information and get good results without the specific knowledge of the wall reflection coefficient. Note that the frequency resolution in the case of mixing is equal to the length of speech signal and in the case of de-mixing is equal to the length of the window.

Table 3 shows the effect of window size on SIR improvement for the wide spacing case. As the size of the window is increased, the inverse filter gives improved results, with the best results for a window size equal to the length of speech. The next step is to use the measured impulse responses using ESS in place of the simulated early reflections model. The experimental data in the recording sessions were done with wide spacing much more than 4 cm. It is expected that the IR measurements will be sufficiently accurate to give good results. FIR approximations to the IIR inverse filters will also be tested.

## Conclusions & Future Work

The results presented above are very preliminary. We are working towards a robust audio zoom (source separation) method which is partly blind and partly aided by the measured impulse responses.

**Table 2. Parameters used for simulation non-blind source separation**

| | |
|---|---|
| Sampling Rate | 16 kHz |
| STFT frame size | 1024 points (64 ms) |
| STFT frame shift | 512 points (32 ms) |
| Frequency bins | 512 |
| Reflection Coefficient of wall | 0.5 |

**Table 3. SIR improvement with increasing window size for the wide spacing case.**

| | | | |
|---|---|---|---|
| Window size | 1024 | 2048 | 4096 |
| SIR Improvement (dB) | 8.6 | 10.9 | 12.6 |

**Acknowledgements**

The author would like to thank Professor Bastiaan Kleijn for his helpful suggestions in planning the recording session. We would also like to thank Neil Maddever from Sounds Unlimited for his recording expertise and Dr. Rajeev Nongpiur for his contributions to discussion of the analysis

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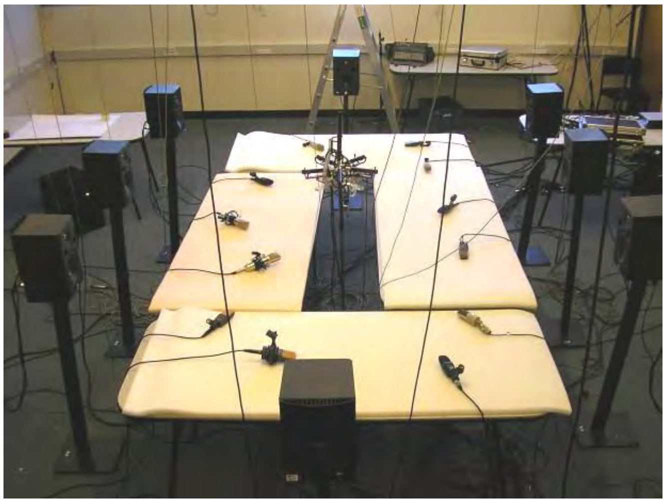

**Figure 3. One of the layouts for simulating people having conversations around an audio/video conference table.**

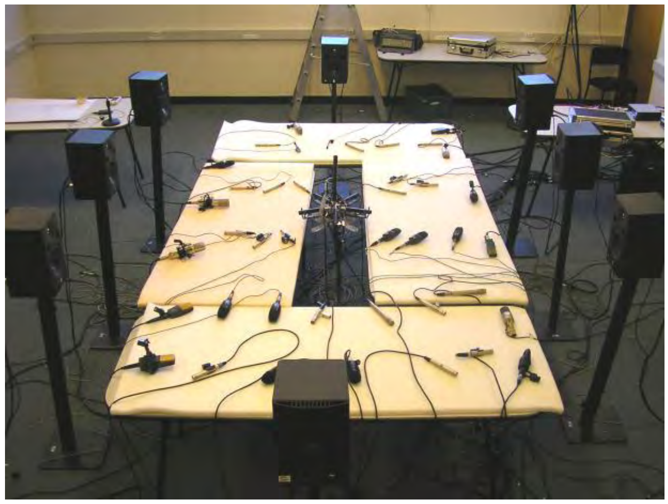

**Figure 4. The final layout corresponding to recording 10 in Table 1, with all 48 microphones in place.**


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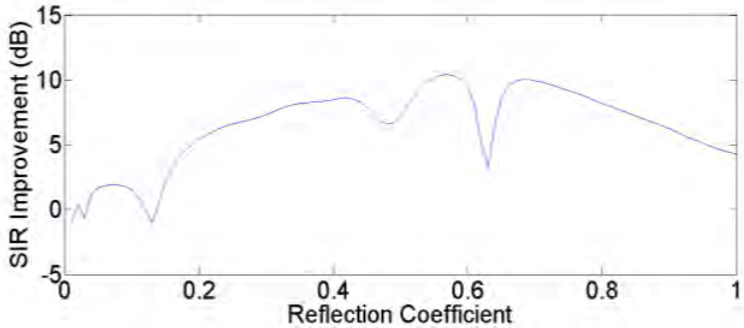
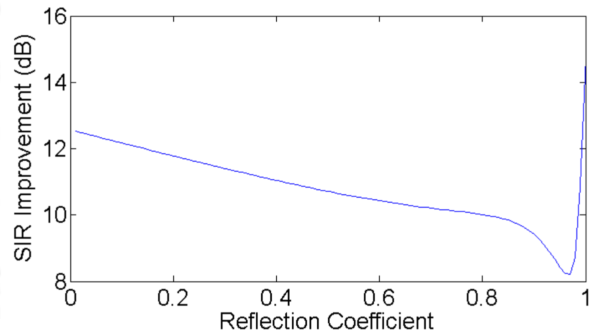



Figure 5. SIR improvement versus reflection coefficient for wide spacing of microphones.

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# A Pilot Study on the Acoustic Environment in Early Childhood Centres

**Stuart J. McLaren**

**Massey University, Wellington Campus, New Zealand**

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## Abstract

A comprehensive study has investigated the sound exposure that children and teachers receive in childcare centres. A small extra study investigated the hearing acuity of teachers. Personal sound exposures were measured on 73 teachers in early childhood education centres and compared to the prescribed levels for workers in the health and safety in employment legislation. Twenty eight teachers in part-time (sessional) centres and 45 teachers in all day centres were tested over one or more working days. One staff member of a sessional centre and five of those in all day centres received noise exposures well in excess of the 100% maximum daily sound exposure permitted in the workplace. Standard hearing tests were conducted on a small group of 20 teachers including young adult workers and those nearing their retirement. There was a noticeable increase in hearing loss as age increased with significant loss evident in the older participants. Reverberation times were measured in 30 early childhood learning spaces with most of the centres exceeding the 0.4 - 0.6 seconds prescribed by the Australian and New Zealand standard for classrooms and learning spaces.

## Introduction

Noise exposure levels and resultant health issues of both teachers and children have become of increasing importance in early education. Noise issues were identified in the consultation process leading to the promulgation of the Education (Early Childhood Services) Regulations 2008 [1] and the Licensing Criteria for Early Childhood Education and Care Centres 2008 [2] made pursuant to the above regulations. Noise levels in early childhood centres are usually generated as part of the centres' activities and from intrusion from activities outside the centre.

### Legal tools

Noise induced hearing loss from occupational exposure is always of concern in noisy work environments. New Zealand has adopted the most widely used international criteria in the Health and Safety in Employment Regulations 1995 (Regulation 11) [3]. This requires an employer to take all practicable steps to ensure no employee is exposed to sound pressure levels in excess of:

- An A-frequency weighted time-average level over an 8-hour working day of 85 dB ($L_{Aeq\ 8h}$ = 85 dB) or equivalent. This can be expressed as 1.0 $Pa^2$hr or 100% dose
- A peak level ($L_{peak}$) of 140 dB

The Approved Code of Practice for Management of Noise in the Workplace [4] promulgated under the Health and Safety in Employment Act 1992 [5] gives guidance and preferred work practices to meet the requirements of the legislation. However, it was never envisaged that the provisions relating to noise in the legislation itself or the code of practice would apply to schools and early education environments as a work place. If these provisions were applied to education environments, children could be isolated from their teachers, and/or the teachers would be required to wear hearing protectors. It is clear that this legislation was never designed to address noise generated in the classroom and similar learning spaces as such measures would be completely impractical in these settings. The above legislation and the approved code of practice would need major revision if it were to be made applicable to exposure for teachers in early education and school teaching environments.

Although not obviously covered by the employment legislation, children too can be affected by excessive noise levels in early childhood centres. The recently enacted legislation requires that all reasonable steps are taken to promote the good health and safety of children enrolled in the centre or service [1]. Underpinning that, the Health and Safety Criterion No 15 [2] requires that all practicable steps are taken to ensure noise levels do not unduly interfere with normal speech and/or communication or cause any child attending distress or harm.

## Acoustical Quality of Early Childhood Centre Learning Spaces

The "acoustical quality" is another important factor in mitigating or enhancing existing sound pressure levels. The interrelationship between these two acoustic parameters can be shown by the figure below, shows that despite the number of speakers remaining constant, poor reverberant learning spaces can set a cyclic pattern in motion leading to increasing noise levels as speech levels are raised in an attempt to counteract degraded speech intelligibility (see Figure 1). This phenomenon is known as the Lombard Effect.[6] Good acoustical quality can therefore lead to significantly quieter teaching environments.[7,8].

Oberdorster and Tiesler [7] describe short reverberation times as the most important room acoustics parameter in the classroom and similar learning spaces for the general mitigation of noise levels and enhancement of speech intelligibility.

The AS/NZ standard for building interiors [9] recommends a reverberation time (T60) of 0.4-0.6 seconds in classrooms and learning spaces. For young children, who are immature listeners, and for those experiencing hearing loss and auditory processing difficulties, a reverberation time of 0.4 seconds creates the optimum acoustic conditions.

## Noise Induced Hearing Loss

One of the most common forms of hearing loss is that caused by prolonged exposure to excessive noise. This is referred to as noise-induced hearing loss (or noise-induced permanent threshold shift) which is usually of gradual onset and irreversible. Noise-induced hearing loss begins as a result of the degeneration of the hair cells in the inner ear (organ of Corti) in the frequency region of 3,000-6,000 Hz.[10,11]

In normal healthy hearing, the hearing threshold level does not fall below 20 dB across the audible frequencies. A typical audiogram indicating noise-induced hearing loss shows the characteristic dip or V shape in the frequency range of 3,000 to 6,000 Hz (see Figure 2).

## Experimental

The study and analysis was planned with the following three research questions:

1. What are the typical sound exposure levels experienced by early childhood centre staff?
2. What is the hearing status of New Zealand early childhood teaching staff?
3. What is the typical acoustical quality of early childhood centre learning spaces in New Zealand.

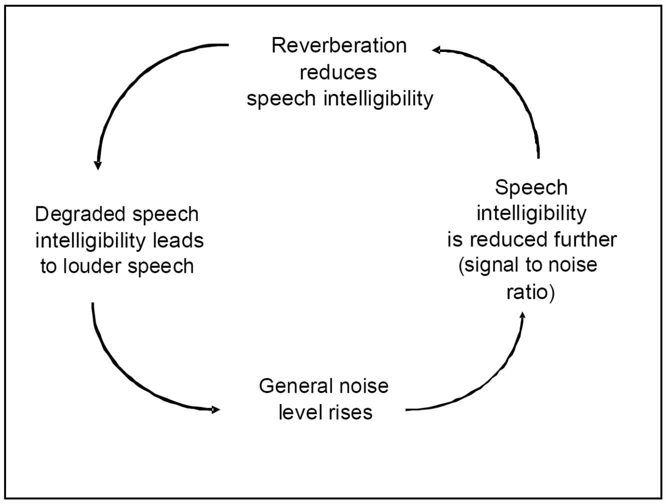


**Figure 1. Cyclic interrelationship of noise levels and acoustical quality. Adapted from Oberdorster and Tiesler (2008).**

### Personal sound exposures of staff

In addressing the first research question, three daily sound exposure categories were formulated. Those of less than 50% of the maximum permitted dose do not present any concern because they are well below the permitted maximum of 100%. The second category (50-100% dose) still complies with the legislation but is approaching the maximum permitted level and finally the third category (greater than 100%) is of major concern because it transgresses the legal requirement.

As length of exposure is a critical factor in determining the levels of sound exposure, the participating early childhood centres were selected according to the licensing categories of the former legislation (in force at the time the investigations were carried out) [12] which included a selection of sessional centres (kindergartens) and all-day centres. In general, children will be enrolled in kindergarten at 3-years of age and attend 2-hour sessions in the afternoon for three days a week. Children 4-5 years of age attend 3-hour sessions in the morning for five days a week. All-day centres principally provide childcare for working parents and those who choose full time early education. This sector caters for all preschool children from new-born babies right up to age 5. Centres were licensed as required by the legislation [12] as either all-day centres (Part 1) or sessional centres (Part 2). Within each part, there are separate licensing sub-categories for children under 2-years old (all under 2) and those 2-years old and over (all 2 or over). There is an additional licensed category for mixed ages which in effect combines the two age subcategories allowing children from new-born to 5 years of age to be present in the same centre. This mixed age licence will only be granted where the Secretary (of Education) is satisfied that sufficient care and protection is provided for children less than 2-years old (Regulation 37) [12].

Daily sound exposures of individual teachers were recorded using Cirrus lightweight dose Badges and personal sound exposure meters (dosimeters) for teaching and contact staff. A total of 73 staff members (45 participants from 20 all day centres and 28 participants from 12 sessional centres) had been evaluated. All the centres except one were established in buildings converted from a previous use and had no acoustical treatment such as acoustically rated wall and ceiling panels. The personal sound exposure equipment recorded the following relevant data:

- A-frequency weighted time-average level ($L_{Aeq,t}$ dB) for the entire work period "t"
- Daily sound exposure expressed as pascal squared hour or % dose. A noise dose of 1.0 $Pa^2hr$= 100% does and equivalent to an A frequency weighted time-average level of 85 dB over an 8 hour day or equivalent energy to this amount.
- C weighted Peak level ($L_{Cpeak}$ dB)
- Time history for each event.

### Pure tone audiometric testing

The second research question involved the hearing status of the teaching staff. Audiometric testing was carried out before work began. This part of the study originated from a number of requests from early childhood centre staff expressing concern about their hearing status and requesting the research team for assistance. Despite the number of requests received, the work culture of long hours and rosters made the conducting of testing very difficult. Tests were scheduled between 5am to 7am to allow enough time for all participants to be tested before work and again after each worker had finished for the day. This meant that only the two large centres that were located close to Massey University could be considered. While it is ideal that testing be done in an approved hearing test booth, no unit was available.

The 20 participants' age range was 20 – 60 years old. The age categories and numbers in each are given in Table 1.

Audiograms were taken with the current standardised procedure for presentation of tones prior to the start of the working day to establish the normal hearing threshold of each participant (Research question two). A screening audiometer (GSI17) was used and audiometric testing was done either at Massey University or at the particular early childhood centre.

Participation was completely voluntary but all the staff that were present at the testing times wished to participate. The necessary ethics committee approvals were obtained and the conditions of approval and the requirements of the Health and Safety in Employment Act 1992 [5] for testing of workers were strictly applied.

Background noise presented major issues in conducting the audiometric testing as no audiometric booth was available. Staff from the first centre elected to have their hearing tested before the start of work at Massey University. Even though the Massey University space was normally very quiet, the noise of heavy rain on the roof and water running down gutters became a major source of distraction. There were major difficulties in detecting the tones in the lower frequencies probably due to masking effects. Staff from the remaining centres wished to have their evaluations done at their premises, but with no quiet space a number of the tests had to be done while children were present with the noise presenting a major source of distraction. In addition, time was constrained with staff having limited time available before commencing duties. The noisy testing conditions and time constraints compromised reliability. However the results were useful as many participants had not had their hearing tested before and were able to gain an approximate status of their hearing.

In addressing the third research question, reverberation times were measured in 30 early childhood centres. Measurements were taken with an 01 dB Solo Master sound level meter mounted on a tripod (1.2-1.5 metres from the floor) and set to T60 mode with a trigger activation level of 90 dB. The sound source was provided by a starter gun with powder caps.

Many of the centres had no form of acoustical treatment of internal surfaces. Three centres had acoustical treatment retrofitted enabling the effect on acoustical quality to be monitored. One new purpose-built centre was professionally designed to meet the criteria for learning spaces of the Australian and New Zealand Standard [9] and had full acoustic treatment applied as part of the construction.

## Results

### Daily sound exposures of teachers

The daily sound exposures (or daily noise doses) recorded in the study together with the number of participants are presented in Table 2.

### Peak levels

The highest level permitted under the Health and Safety in Employment Regulations 1995 is 140 dB.

**Table 1. Participants in hearing tests**

| Number of participants | Age category |
|---|---|
| 6 | Less than 20 |
| 8 | 20-30 |
| 3 | 30-40 |
| 2 | 40-50 |
| 1 | Over 50 |

**Table 2 Daily sound exposures and teacher numbers**

| Daily sound exposure | All day centres | Sessional centres | Total 73 |
|---|---|---|---|
| (% dose) | 45 centres in total (% of total) | 28 in total (% of total) | (% of total) |
| <50% | 31 (69%) | 23 (82%) | 54 (74%) |
| 50-100% | 9 (20%) | 4 (14%) | 13(18%) |
| >100% | 5 (11.0%) | 1 (4%) | 6 (8%) |

- In all day centres 19 participants of 45 in total (42%) recorded at least one peak level exceedance over 140 dB.
- In part time sessional centres, 11 participants of 28 in total (39%) recorded at least one peak level exceedance over 140 dB
- In all day centres and part time (sessional) centres combined, 30 participants of 73 in total (41%) recorded at least one peak level exceedance over 140 dB.

Due to limitations of the equipment, further information on the numbers of exceedances, when they occurred or the peak levels received could not be determined.

### Hearing status of participants

While the effects of difficult test conditions cannot be discounted, half of the participants tested showed the likelihood of developing noise-induced hearing loss, which is characterised by an increase in the threshold values in the 3000- 6000 Hz frequency range (or the ‘characteristic dip’ at these frequencies as shown in Figure 2).

In the younger teaching staff (20-25 years of age), noise induced-hearing-loss was not evident from their audiograms. The audiograms of several participants in the 30-35 age-bracket presented a small notch or V shape in the 3,000-6000 Hz region, which is characteristic of noise-induced hearing loss. This trend continued with a noticeable increase in the level of noise-induced hearing loss as age increased. The two participants in the 40-50 age group both showed significant hearing loss, and the participant in the over 50 age bracket experienced the highest level of hearing loss. The audiogram is given in Figure 3. This participant would be classified as presenting with moderately severe hearing loss.

Further investigation is urgently needed to determine the extent of hearing loss, which exists in teachers of the early education sector and the amount that can be reasonably attributed to occupational exposure.

### Acoustical quality of learning spaces

Of the 30 early childhood centres chosen most had reverberation times between 0.6-0.8 seconds in the important frequencies of 500, 1000, and 2,000 for speech production and intelligibility. Three existing centres complied with the criteria of 0.4-0.6 seconds in the important frequencies. The new purpose built centre with full acoustic treatment met the optimum conditions for young children of 0.3- 0.4 seconds in the important frequencies. This centre was fitted throughout with acoustic wall vertiface composition panels (NRC =0.4, NRC = Noise Reduction Coefficient; an NRC of 0.4 means a 40% reduction of reverberated noise) and the acoustic ceiling tiles (NCR=0.8). The centre was also insulated to mitigate noise intrusion from noise generating activities outside the centre.

Two centres following the initial evaluation, decided to undertake professional acoustical treatment. Descriptions are given as Cases 1 and 2 below.

### Case 1

A sessional centre with a staff of two and an enrolment of 30 children carried out acoustical treatment of the walls. These surfaces, except for some upper areas were covered with New Zealand manufactured vertiface composition

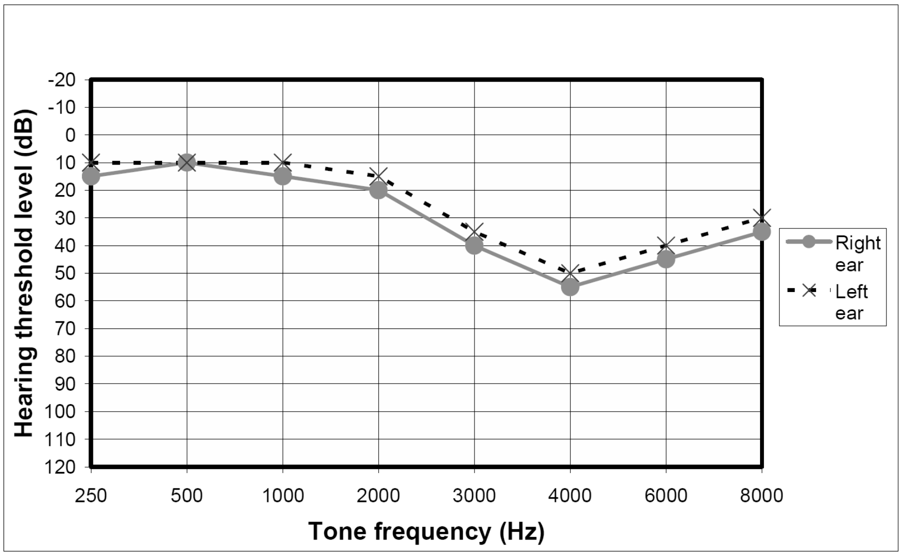


**Figure 2. Audiogram showing a typical noise-induced hearing loss in both ears. Adapted from Occupational Safety and Health (1994) [10].**

acoustic wall covering (NRC = 0.4). The walls were covered fully from the floor to the underside of the sill of the upper windows. The reverberation times before the treatment and after the installation are presented as a graph in Figure 4.

There has been a noticeable improvement in reverberation times as a result of the vertiface composition wall panel application with reductions of up to 0.3 seconds in the important frequencies. This centre now complies with the recommended reverberation times (T60) of 0.4-0.6 seconds for classrooms and learning spaces.[9] These times could be further reduced by fitting acoustic tiles to the ceiling.

### Case 2

This sessional centre had generated many complaints from staff. The reverberation times were the highest recorded of any centre. Acoustic treatment was applied to the walls with vertiface composition wall covering (NRC = 0.4) and an acoustic blanket (NRC = 0.8) attached to the underside of 50% of the ceiling surface.

As can be seen in Figure 5, acoustical treatment of the walls and 50% of the ceiling area resulted a 0.3 second improvement in reverberation times in the important frequencies (500, 1000, 2000 Hz). While these times are still above the recommended reverberation times of 0.4-0.6 seconds [9], this treatment resulted in a substantial improvement in acoustical quality. If the acoustic treatment were to be applied to the complete ceiling area, it is likely to reduce the reverberation times to 0.4-0.6 seconds.

## Discussion

The first research question investigated the typical sound exposures for early childhood centres staff. Six participants out of a total of 73 participants (8%) recorded daily sound exposures well in excess of 100% dose, the maximum permitted level under the legislation.[3] A further 13 participants (18%) received daily sound exposures of 50-100% and 54 participants received exposures less than 50% dose. While there has been an improvement on the levels reported earlier in the progress study by McLaren and Dickinson [13] with an increased sample size, it is still of concern that a significant number of teachers recorded levels in excess of the maximum permitted daily sound exposure. A similar study by Grebenikov [14] in Sydney of 25 full-time teaching staff using similar equipment and the same criteria as adopted by the New Zealand legislation, had one staff member with a daily sound exposure in excess of 100% and three staff members close to the maximum.

The second research question investigated the hearing status of a small group of early childhood workers. Despite the problems with the testing environment, three of the workers showed significant hearing loss and a further seven showed clear signs of a developing hearing loss with the characteristic V shape in their audiograms beginning to form. While likely contributions from non-work activities such as noisy leisure activities have not been investigated in this study, it is of concern that half those who participated either showed significant levels of hearing loss or showed a risk of developing significant levels of hearing loss during their working lives.

The excessive personal sound exposure rates recorded on staff suggests that this may be an important occupational issue for teachers in early education environments. A comprehensive study is needed to examine the temporary threshold shifts in hearing of a cross section of early childhood education staff and relate this to the levels of noise exposure. In particular, investigation of staff members who receive noise exposures greater than the maximum permitted dose of 100%, is justified. Furthermore, a dedicated study is now needed to establish the hearing status of teachers and contact staff in the early education sector and to establish the extent of hearing loss due to occupational exposure when compared to other noise contributing activities outside work.

The third research question revealed that few of the existing childcare centres in the study had any form of acoustic treatment. Reverberation times were above those prescribed by the Australian and New Zealand Standard. On the other hand, one of the few new purpose-built centres with full acoustic treatment incorporated, was shown to meet the optimum acoustical quality. However, the retrofitting of acoustic wall and ceiling coverings to those centres not meeting the criteria prescribed by the standard, was shown to significantly improve the acoustical quality. Due to scarce resources in this sector, it is not possible for many centres to engage professional advice to carry out acoustic treatment. Low cost solutions and DIY (do it yourself) options could be explored which may result in improvement even if they do not meet the optimum level.

The development of a resource kit could be implemented giving a wide range of solutions to improve acoustical quality of learning spaces.

The Department of Labour has not considered this sector of workers as being at-risk from excessive noise exposure at work, and this now needs immediate attention. It is of considerable importance to investigate thoroughly the extent of occupational noise exposure with this group of workers, and if a significant risk is established, to implement regular testing programmes as is done with other at-risk work places. It may be necessary, based on establishing the level of risk among these workers, to propose amendments to address occupational noise issues in the legislation and the associated code of practice as applicable to this profession.

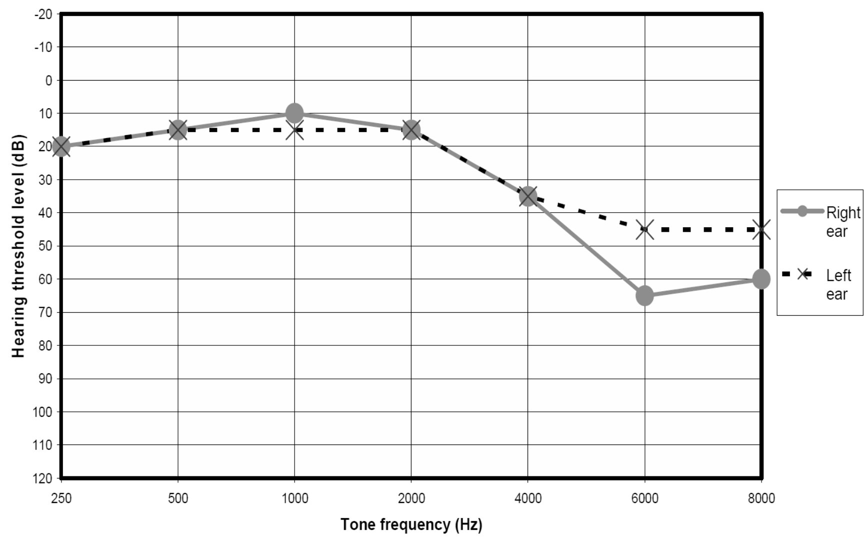


Figure 3.: Audiogram of a staff member aged 60-65 years.

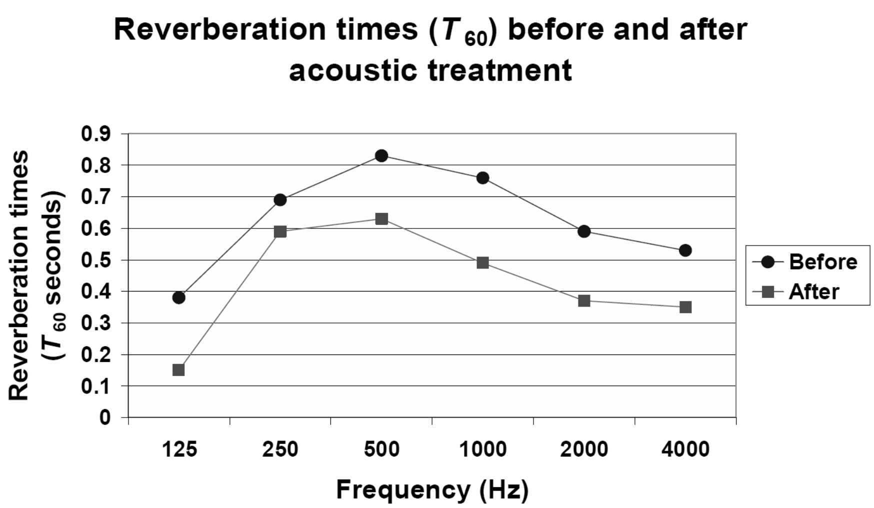


Figure 4 Reverberation time as a function of frequency (Case 1).

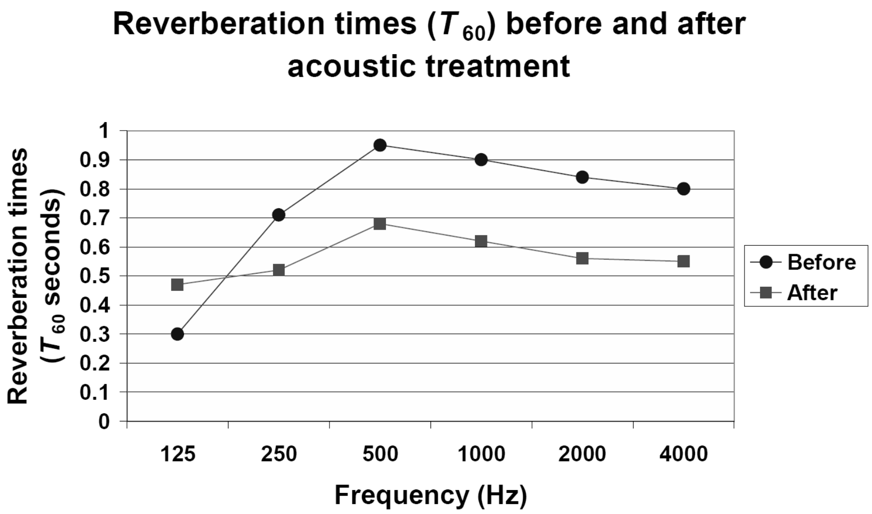


**Figure 5. Reverberation time as a function of frequency (Case 2)**

## Recommendations

The following recommendations are proposed:

- A wide ranging national study be undertaken of teachers and assistants across the early education sector to establish levels of excessive noise exposure and hearing loss attributable to the work environment.
- The Department of Labour and the Ministry of Education ensure that regular testing programmes are introduced for occupational hearing loss and noise exposure among early childhood staff.
- A resource kit be developed to give a range of options for early childhood centres to manage and mitigate noise levels.

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## Venetian Acoustics Rediscovered

Renaissance Venice nurtured great musical innovations. Complex polyphonic, or multipart, music and the novel coro spezzato, or split choirs, were written for festivals and performed in the city's grand basilicas. But the Venetian basilicas and giant churches that still stand today have terrible acoustics for that kind of music. The subtleties of polyphonic music and the spatial "stereo" effect of the split choirs are jumbled and lost in the rumbling echoes of the vast, lofty chambers. How could Renaissance audiences have appreciated the music?

There are two answers to that question, according to a new analysis by music technologist Braxton Boren of New York University and physicist Malcolm Longair of the University of Cambridge in the United Kingdom. Boren and Longair created computer models of two famous Venetian venues and their acoustics and presented the results at the Acoustical Society of America Meeting in San Diego, California in September.

The two obtained detailed acoustical measurements for the famously beautiful Basilica of San Marco and Palladio's Redentore, both in Venice. They used the measurements to construct acoustic models of the two churches on a computer. After consulting with architectural historians, they calculated the acoustical properties of the tapestries, wooden chairs, and crowds of people that would fill the churches on a festival day, when polyphonic and split choir music would be performed.

Today, the reverberation time is almost 7 seconds in the modern San Marco and slightly more in the Redentore when the churches are empty. Such long reverberations blur polyphonic music and ruin the effect of the split choir. But on festival days, filled with decorations and people, the Redentore's reverberation time was cut in half. This would have made polyphonic music clearer but somewhat quieter.

*© Adapted from Science Now http://news.sciencemag.org*

*Kim Krieger*

## Mushroom Music

A soggy wooden board carpeted in soft white fungi doesn't look like much, but in the right hands it can become a world class violin. According to a recent sound test before about 180 people, a fungi infested violin bested a multi-million dollar Stradivarius.

Ninety nine percent of wood-attacking fungi create loose and soft wood that has strange acoustic properties. By measuring how sound echoes through a tree, scientists can get a good idea of how healthy the tree is.

While using sound waves to check up on trees, Francis Schwarze, a scientist at the Swiss Federal Laboratories for Materials Testing and Research, noted that a handful of fungal infections didn't produce widespread rot. The density of the wood decreased slightly, but the speed of sound remained the same. Schwarze and Swiss violin maker Michael Rhonheimer decided that they would try to make a violin out of fungi-treated wood and see how it sounded.

Generally speaking, the treated wood sounds warmer, a combination of increasing the dampening factor that makes high notes more palatable to the ear, and an increase in the radiation ratio, or the ratio of the speed of sound to the density of the wood.

According to Schwarze, treating the wood with fungi artificially recreates the structure of the wood that was naturally occurring during Antonio Giacomo Stradivarius's lifetime. The Little Ice Age, a period of abnormally cool weather between 1645 to 1715, made trees create more uniform wood.

Using four violins, two treated and two untreated, and a Stradivarius valued at $2 million, British violinist Matthew Trusler played for an audience of more than 180 people earlier this month at a forestry conference.

More than 90 people ranked the violin treated for nine months as the Stradivarius. Matthew Trusler's real Stradivarius came in second, followed by the violin treated for six months. The two untreated violins came in last.

*© Adapted from an article at: http://news.discovery.com/*

*Eric Bland, Science Contributor*

# Quiet Area Definition in the Implementation of European Directive 2002/49/EC

**G. Licitra[1], C. Chiari[2] ,E. Ascari[3] and D. Palazzuoli[1]**

[1]ARPAT Environmental Protection Agency of Tuscany Region, Florence, Italy

[2]ARPAT Environmental Protection Agency of Tuscany Region, Pisa, Italy

[3]CNR-IDASC Institute of Acoustic and sensoristic science "O.M. Corbino", Rome, Italy

*A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland*

## Abstract

The Directive 2002/49/EC requires that Action Plans for agglomeration should aim to protect quiet areas too: they have to be identified not only in open country, but also in an urban context. However, there is not yet an international agreement and a robust method to perform this identification; many approaches have been proposed from the non-acoustic one (distance from major sources of noise, public accessibility; function as a recreational space; population density; presence of sensitive buildings) to the mixed one, in which a maximum sound level is also fixed ($L_{den}$ < 55 dB(A) in an area greater than 4.5 ha). The importance of quiet areas will increase with the second step of the Directive implementation that will regard cities with more than 100,000 inhabitants (more than 1,000 cities in Europe): large parks are not common, so it could be convenient to determine small areas where people could relax without spending too much time to reach a quiet extra-urban location. In this paper a method to determine possible "neighbourhood quiet areas" has been tested in the city of Pisa (Italy) belonging to the second step. Road traffic noise has been recognized as the principal annoying source, therefore, areas with road noise $L_{day}$ < 55 dB(A) have been identified and selected with a GIS techniques based on land use (parks, green historical and sensitive areas) and dimensional criteria. A post-process selection has been performed taking into account also the other noise sources in order to allow decision makers to evaluate resources availability and to develop specific Action Plans..

## Introduction

The European Directive 2002/49/EC, relating to the assessment and management of environmental noise [1], aims "to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise".

It also defines for all Member States common environmental noise indicator: $L_{den}$, which is a weighted energy sum of noise equivalent levels during day-evening-night periods, defined in Italy as $L_{day}$ 6am-8pm, $L_{evening}$ 8pm-10pm and $L_{night}$ 10pm-6am. Furthermore, it defines quiet areas, which are obviously important to compensate annoyance and stress caused by noisy home and work environments.

However, the definition of a quiet area is not unique within the Directive and two kinds of areas can be distinguished:

- A Quiet Area in agglomeration that "shall mean an area, delimited by the competent authority, for instance which is not exposed to a value of $L_{den}$ or of another appropriate noise indicator greater than a certain value set by the Member State, from any noise source" (art. 3, lett. l);
- A Quiet Area in open country that "shall mean an area, delimited by the competent authority, that is undisturbed by noise from traffic, industry or recreational activities" (art. 3, lett. m).

Both areas are to be protected and actions have to be planned in order to comply with the Directive requirements. Nowadays the greatest problem is still defining a shared procedure and noise limit values in order to identify quiet areas especially in agglomerations. During recent years, some Member States (MSs) have already tried to set up criteria and methodologies to define quiet places: generally these criteria are based both on acoustic properties and geographic distance from the major noise sources. Different approaches will be discussed in the following paragraphs.

In the first part of the paper the main approaches will be described and applied to the municipality of Pisa, a small town in the Tuscany region, Italy (about 100,000 inhabitants). In Italian legislation, before the acknowledgment of the European Directive, quiet areas were not clearly defined. The legislation established in 1991 sets noise limits for areas whose primary usability requirement is quietness. Usually those limits (50 $L_{day}$, 40 $L_{night}$) are suitable for natural parks and other not urbanized areas but they may be applied to historical sites too.

The authors believe that those limits are not adequate to identify quiet areas because these areas may have a higher noise level but may still be a place to stay away from town noise and relax. So we define quiet areas in agglomeration as neighbourhood quiet zones (even if small) whose punlic accessibility is the main property. Therefore, a new approach for small town is proposed that could be applied for similar Italian cities. In fact, we believe that perceiving quietness is something related not only to acoustic criteria but also to how public places are perceived by inhabitants: this is a cultural factor related to local practise of sociability and to attitude to noise sources by competent authorities [2], and it could not be easily taken from other European contexts. This belief is confirmed by a current tendency, which leaves decisions about quiet areas to local authorities.

## State of the Art: Available Approaches

### Acoustical criteria

Some MSs have already adopted noise level limits for quiet areas [3] but only in Norwegian legislation are they defined in terms of $L_{den}$ according to the Directive 2002/49/EC. At the moment some suggestions and reports are available form EU research projects:

1. The study of Symonds Group [4], required by the European Union, that recommends limits for quiet area in agglomeration (50 dB $L_{den}$) and in open country (40 dB $L_{eq}$,24h);
2. A study of the Irish Environmental Protection Agency EPA[5] suggests a 30 dB $L_{90}$ limit for not geophonic or biophonic sounds in open country;
3. A Finnish study [6] remarked that quietness level should differ according to the context and suggested 45 dB during the daytime in agglomeration, a 35-40 dB range in rural areas and 30-35 dB in natural parks and where human activities are not frequent.

Considering these low noise level limits, public experience in quiet areas is not usually considered in the mapping procedure.

In order to analyse in detail this topic a study has been carried out in Amsterdam to identify and map quiet areas [8]. Also in Amsterdam citizens have been involved in giving feedback about the real usability of different sites.

### Distance based criteria

Other methodologies to identify quiet areas start from geographic considerations using urban planning approaches based upon distance criteria. Both the Irish EPA study and the Finnish one [5, 6], suggested different distances from main towns and infrastructure.

A similar approach was also suggested by the Campaign to Protect Rural England (CPRE) [9] to identify quiet areas in open country. Distance criteria are suitable to identify large natural areas: in [3] they are compared and areas subtracting buffers of main roads and railways and urbanised sites are identified (see Table 1).

### Table 1: Distance criteria [3]

| Noise Source | Quiet Areas | | Tranquil Areas |
|---|---|---|---|
| | Waugh *et al.* (2003) | Karvinen & Savola (2004) | CPRE (Undated) |
| Motorway/Dual Carriageway | 7.5 km | 4 km | 4 km/2 km |
| National Primary Route | 5 km | 4 km | 1 km |
| Regional roads | ---- | 3 km | 1 km |
| Local roads | ---- | 2 km | --- |
| Railway lines | ---- | 3 km | 1 km |
| Air and water transport | ---- | 3 km | ---- |
| Motor sport | ---- | 3 km | ---- |
| Large Towns / urban areas with a population of >10,000 people | 15 km | ---- | 4 km |
| Smaller towns / urban areas with a population of >5,000 people | 10 km | ---- | 2 km |
| Urban areas with a population >1,000 people | 3 km | ---- | ---- |
| Major industry site | 10 km | ---- | ---- |
| Local industry | 3 km | ---- | ---- |
| Largest power stations | ---- | ---- | 3 km |

The goal of such methods is to identify large quiet areas that could be preserved from urbanization and regarded as natural reserves of quietness: a global environmental protection approach is integrated in this concept. These criteria are fixed for large rural areas of these countries, which are not so frequent in Italy. The methods seem unsuitable for the Italian territory, as it is described in the second part of this work.

Moreover, the project [8] defines tranquil areas as 'places which are sufficiently far away from the visual or noise intrusion of development or traffic to be considered unspoilt by urban influences'. Therefore, we notice that this concept is not suitable for agglomeration, in which authorities should consider more factors, especially public accessibility.

### Mixed approaches

A comprehensive approach to identify quiet areas in the first mapping round has been set up by Defra [3], which establishes a short-term procedure for quiet areas in agglomeration. A sequence of filters is applied to a territory to identify quiet areas. The main filters are:

- Land Type: woodland, nature reserves, landscape, country parks, gardens, recreation and sport grounds, playing fields and playgrounds, amenity that are accessible to general public;
- Noise level: area must include a part under 55 dB $L_{den}$;
- Minimum area: the area must be greater than 9 hectares;
- Minimum area of quiet: the area under 55 dB must be greater than 4.5 hectares.

Minimum area filters are optional and they are used to reduce the number of quiet areas so that they became manageable for local administration.

Defra also suggests a long-term procedure that involves local authorities and stakeholders to assess candidate areas; however, this procedure for agglomerations identifies big areas and not small (public) gardens, which are more likely to be accessible and usable.

Small areas do have the same benefits in terms of quiet, as asserted by the Dutch Health Council, which includes quiet built up areas in cities and identifies a different step-wise procedure [9]:

1. A sound must be classified as appropriate/inappropriate or desirable/undesirable for each type of area (nature reserves, green spaces in the countryside, green spaces in cities, quiet built-up areas in cities);
2. The current level of inappropriate or unwanted sound must not exceed a certain 'level of quietness', which can be exceeded only for a limited amount of time;

3. This 'level of quietness' is an expected background level that varies according to the (type of) area;
4. An additional criterion is that it should not be possible to hear any loud inappropriate/undesirable sounds, or that any such sounds that can be heard should be as quiet as can reasonably be achieved given the producer/source of the sound.

Therefore, evaluating quiet areas in urban environment means considering citizen perception of quietness: in fact, more recent studies have also begun to take into account the opinion of the general public, asking them to discover which quiet areas can really be considered to be accessible [2, 7, 10].

## Quiet Areas in Small Cities: Application of Available Methods to the Tuscany Region

Although some methods shown above are oriented to the identification of quiet areas in agglomeration, when applying them to our national territory, it is hard to define areas large enough to be suitable for relaxing and restoring from every day noise.

Evidence of these difficulties are greater applying distance based criteria: An attempt to identify potential quiet areas has been carried out according to the methods listed in Table 1 and summarized in [3]. These criteria have been applied to the Tuscany region with particular attention to the small municipality of Pisa, which includes a large natural reserve of national interest.

The following figures show the results of distance-based approaches:

- The Irish EPA method – Figure 1;
- The Finnish method – Figure 2;
- The English CPRE method – Figure 3; All buffers for each type of noise source (infrastructure or town) are considered as exclusion criteria to identify potential quiet areas, which are defined as resting territory.

Notice that, excepting the Finnish methods, these approaches are intended to identify quiet areas in open country; in particular the CPRE method is oriented to protect tranquil rural areas.

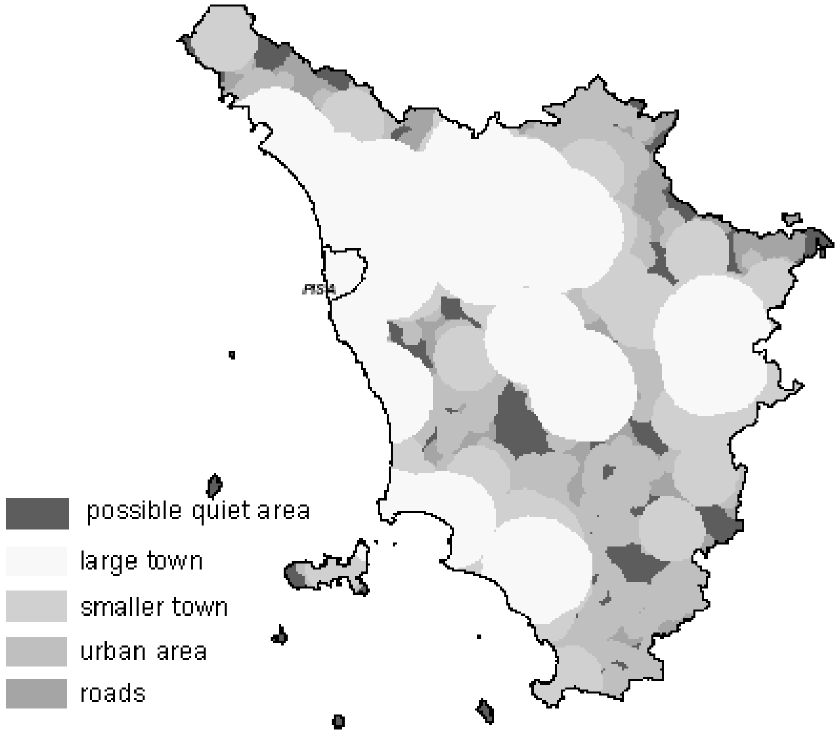


**Figure 1. Irish EPA method [5]. Darker areas are quieter.**

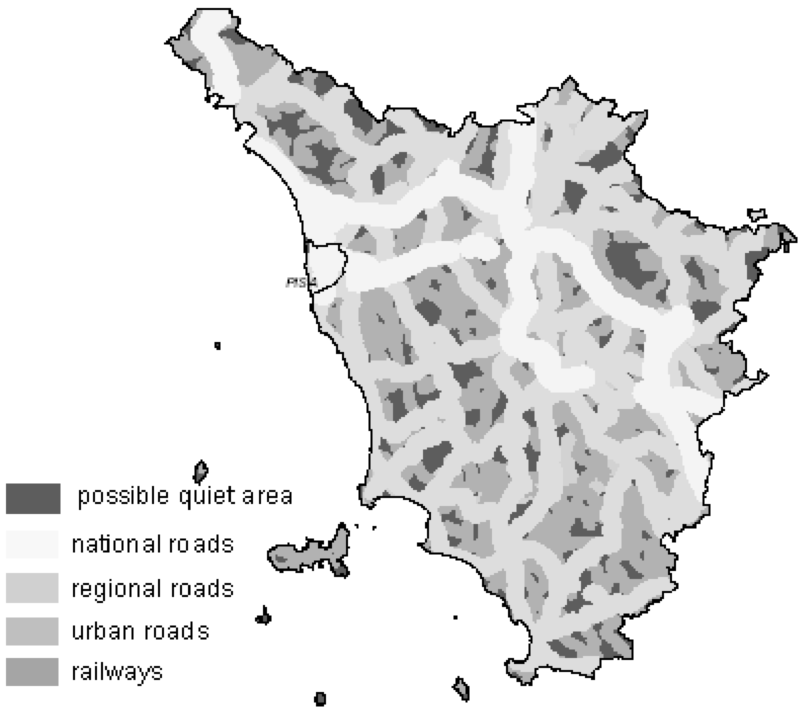


**Figure 2. Finish method [6]. Darker areas are quieter.**

These methods appear to be unsuitable for Tuscany region: in particular the Irish and the Finnish ones are too strict, excluding almost all of the Tuscany region, which is known as a green territory. Better results are obtained with the identification of tranquil areas method: a lot of rural areas far from major roads and town are identified; however, only a small part of Pisa municipality seems to be a quiet area.

Areas identified with those approaches are still unsuitable for every day relax ing not only because they may be not public spaces but also because they are too far away from the home and work places of Pisa inhabitants.

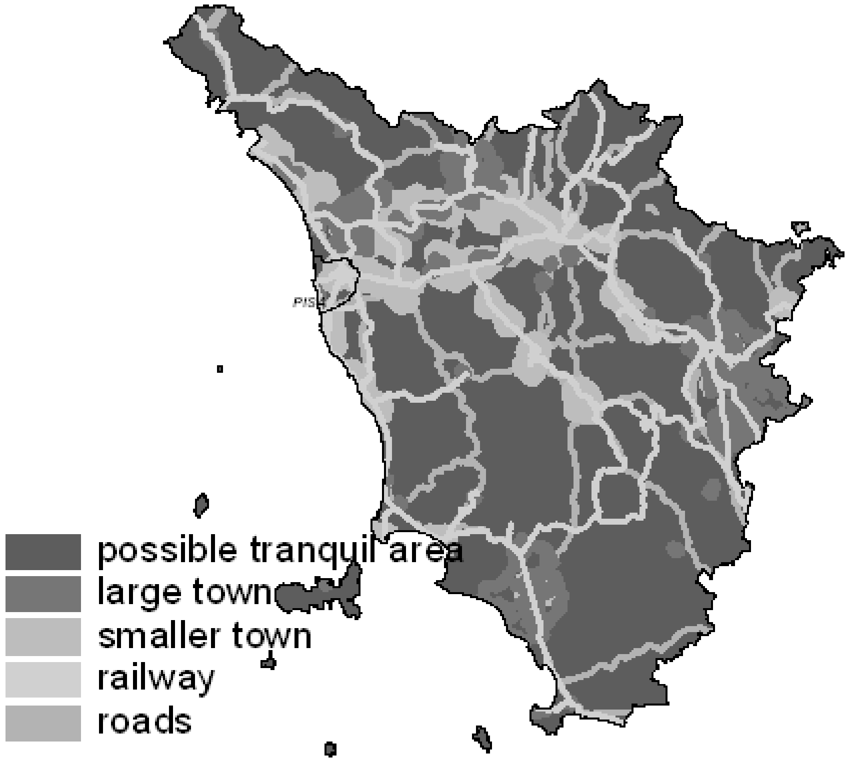


**Figure 3. CPRE tranquil area method [8]. Darker areas are quieter.**

**Figure 4. European study [8] acoustic approach. Lighter areas are quieter.**

Therefore, these methodologies don't reach the aim of quiet areas in a small agglomeration such as Pisa. Better results have been achieved with acoustical criteria approaches: we applied noise threshold level $L_{den}$ < 50 dB(A) suggested in the European study [8], as shown in Figure 4.

The results identify a number of quiet small areas in the city centre that are very accessible. However, the threshold level is not able by itself to select real relaxing city areas because other facets have to be considered: land use, minimum area size, public accessibility and usability.

### Defra Approach: Application

A more detailed and complex approach is the one proposed by Defra, which is a multi-criteria approach with more than one filter. When we applied it to the Pisa municipality, with noise and land type filters, we obtain a too large a number of quiet areas (light areas in figure 5). In fact, almost all areas with low levels have the correct land type.

However, the results when introducing minimum area filters are not better (dark areas in figure 5). In fact, most of the identified areas are located far outside the city centre, in which only small areas are available, and they are agricultural areas or woodland not necessarily accessible to the public.

Therefore, applying dimensional filters we lose important quiet areas in city centre and at the same time we obtain too many publically inaccessible areas.

The reasons for failure of this method (and of the previous one) are mainly due to the context of planning. In fact, in North Europe urban characterization is very different from the Italian one; small spaces in Italian towns don't allow such large areas, therefore we have to use a different approach that could be suitable for a small town.

In the next section an attempt to modify the Defra approach to fit Italian urban characteristics is carried out.

## Neighbourhood Quiet Area: A Defra Italian Interpretation

The Pisa municipality is a quite small one in the Tuscany region (less than 100,000 inhabitants): it carried out strategic noise mapping, even if not compelled by law, taking into account the presence of university students (more than 10,000 new students per year), which are to be considered inhabitants even if not officially registered.

Strategic noise mapping was carried out through a detailed modelling of municipal area, performing calibration measurements (both traffic data and noise levels) and running a noise model [11]; this led to an estimate of noise levels over a 5x5 m spaced grid.

Model results, verified by means of further noise measurements, had good accuracy according to the GPG2 (Good Practice Guide ver. 2 [12]).

The town of Pisa has a large historical city centre (partially closed to traffic) and an enormous amount of traffic around city walls caused by commuting, which is the main noise source.

A city like Pisa with many students and pedestrian areas needs small quiet areas within urban quarters so that quietness will be embedded in an urban milieu. This process should involve citizens expressing their opinions and needs a number of these quiet oases.

**Quantitative phase**

To define a new approach we started from the final aim of defining quiet easy-accessible areas, embedded in an urban context, then we considered the pros and cons of the previously implemented methods and finally defined a new methodology, which is more suitable for a small town.

This new approach is of course a mixed one that identifies areas under a threshold value whose land use is adequate.

Some observations have been taken into account to define a multi-filter procedure:

- Noise levels are analysed to identify quiet areas are $L_{day}$ values: in fact, areas are projected for daytime relaxation and we decided not to consider night time exposure to noise;
- Studies and surveys carried out for the Pisa municipality and Tuscany region [13, 14] highlighted that main annoyance source is the road network; annoyance from a continuous source like road noise is higher than a source with short high peak events like railway or aircraft noise;
- The minimum area size could be smaller than the one of Defra, especially considering the global size of the municipality; moreover, excluding national natural reserve,s there are no big parks but only small green district areas, yards of historical buildings, historical and monumental areas.

The following is the detailed multi-filter procedure that is used for the identification of possible quiet areas in Pisa:

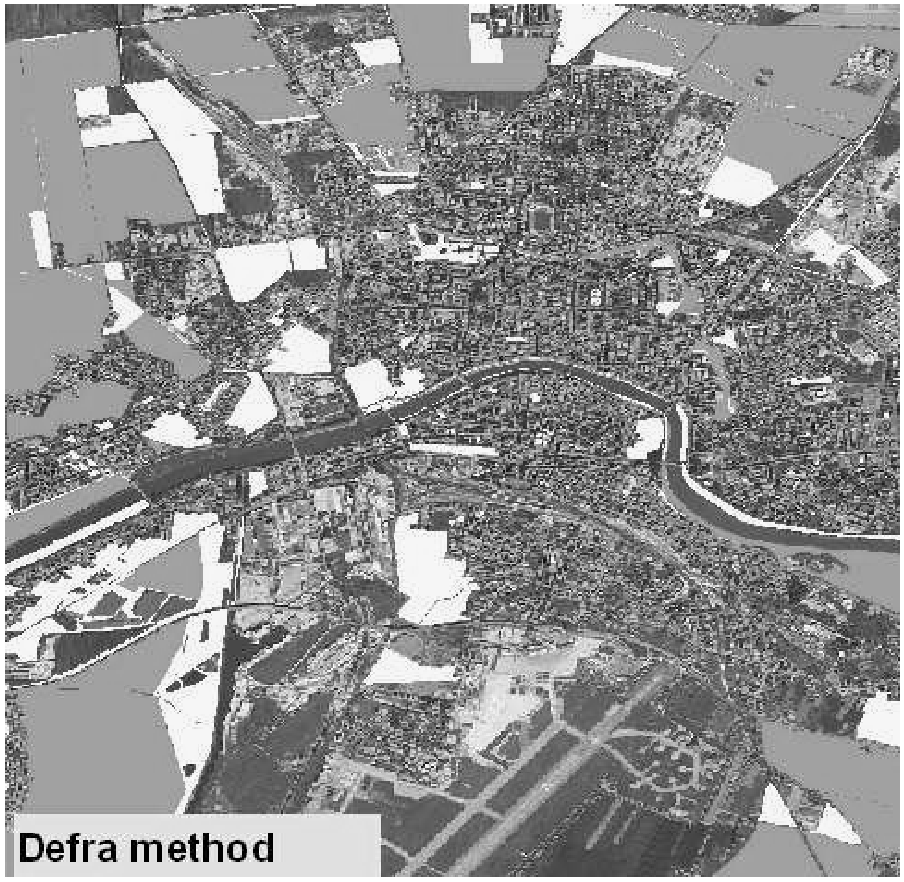


**Figure 5. Defra method [3]. Lighter areas are quieter.**

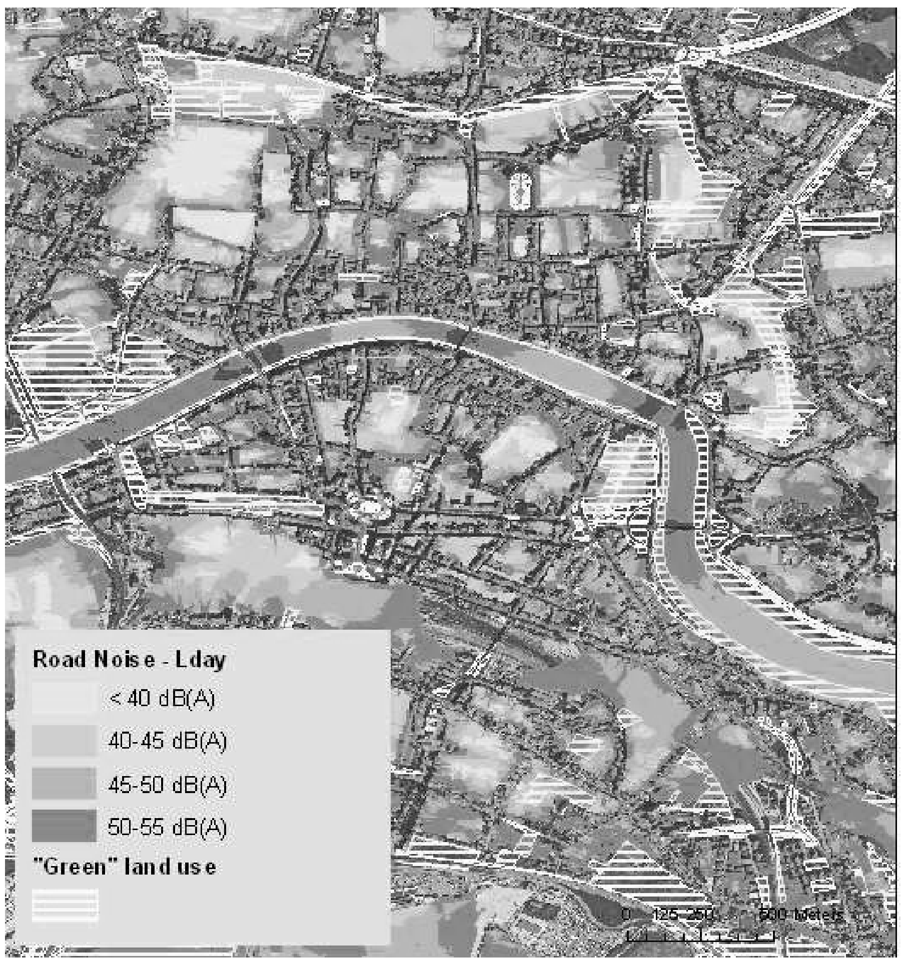


**Figure 6. Pisa city centre -Step 1 & 2-$L_{day}$ < 55 dB(A).**

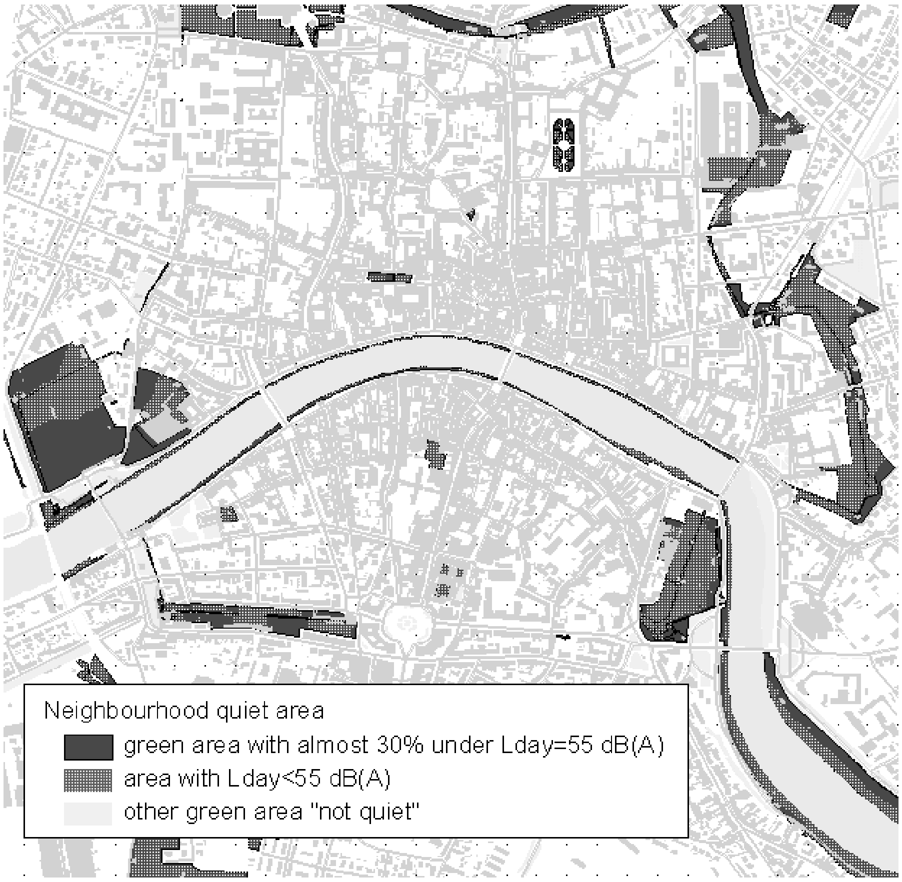


**Figure 7. Pisa city centre. Step 3 Selected 30% quiet areas are dark.**

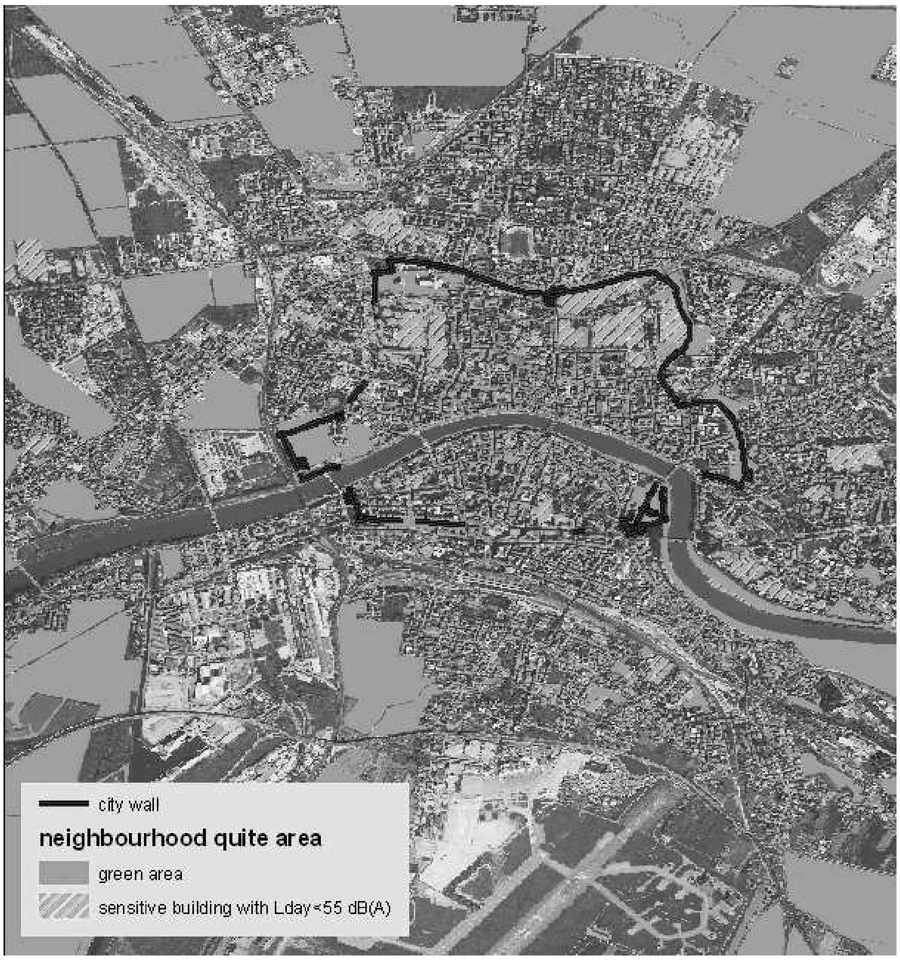


**Figure 8. Pisa city centre. Step 4 Quiet areas and sensitive buildings with $L_{day}$ noise levels under 55 dB(A).**

1. Select areas whose land use characteristics are suitable for parks, green spaces, historical areas;
2. Select area with day time noise road levels $L_{day}$ < 55 dB(A) (notice that the grid resolution is 5 $m^2$) (see Figure 6);
3. Identify from set 1 only the areas whose percentage of quietness, as defined in set 2, is greater than 30% (figure 7).
4. Include sensitive buildings (such as a school, hospital, nursing or retirement home) whose diurnal level ($L_{day}$) doesn't exceed 55 dB(A) (figure 8).

A post process check (figure 9) is convenient to verify if this procedure included areas with too high strategic noise level (areas with strategic levels $L_{day}$ > 65 are deleted).

**Qualitative phase and development post-process selection**

This method also includes areas that may be not accessible to the public: that's why a qualitative phase is needed to select real quiet areas.

This phase may involve not only urban planners but also citizens. Identification of quiet areas by citizens may be a check of the quantitative phase that could be carried out involving citizens living and working near quiet potential areas but also all inhabitants.

The real needs of citizens and the real accessibility of an area not always depends on noise characteristics but sometimes social factor (security, clearness, clean area, landscape, vegetation, ...) are more relevant [7].

In fact, some surveys have been already done [8] but now improvements in web technology (i.e. online social networks) allow a broader approach. An example of this is the e-participating process as described by the Bristol Citizenscape [13] project in which citizens are able to identify quiet areas on a map: both potential and actual quiet areas are identified and comments, audio and video can be added.

Therefore, a similar survey would be suitable also for the Pisa municipality to involve citizens and to know actual needs of people.

Final quiet areas to be included in action plans should be defined by local authorities considering not only acoustic and land type criteria but also citizen needs and sensibility: this process will lead to identification of quiet areas that will provide a concrete possibility of relaxation in every day life.

With these quantitative and qualitative phases, decision makers are allowed to evaluate resources availability and to develop specific action plans that include definition of quiet areas [15]. In this way decision taken by authorities could be more efficient and could be better understood by inhabitants.

## Conclusions

A comparison between different approaches to select quiet areas in open country and inside agglomerations has been carried out. All the applied methods seem not to be suitable for identifying quiet areas in a small municipality, being focussed on large areas. The quiet areas concept and any procedure to select these for local areas should take into account the urban history and cultural heritage: the main characteristics of quiet areas have to be both quietness, usability and "well being" perception. A new promising approach has been developed which considers some peculiar characteristics of the Italian, an in particular, Tuscan small cities.

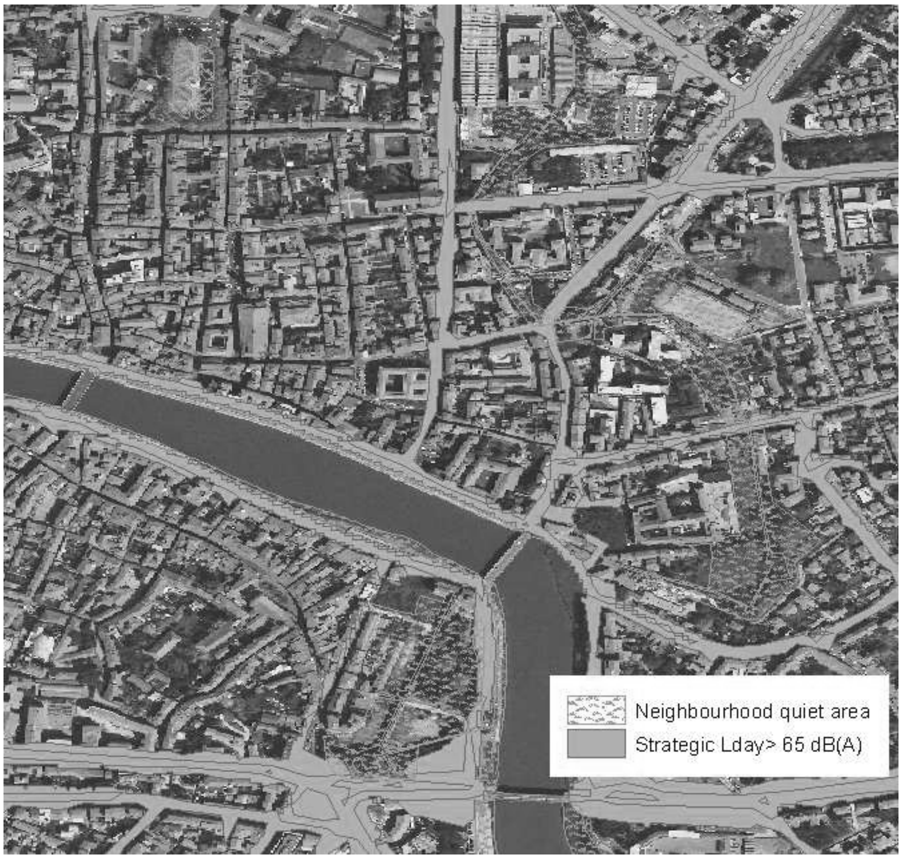


**Figure 9. Post process check of high strategic levels in selected quiet areas**

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# ICA Report 2011

INTERNATIONAL COMMISSION FOR ACOUSTICS

The ICA is the international umbrella organization representing acoustics in the world. It was instituted in 1951 as a sub-committee to the International Union for Pure and Applied Physics, IUPAP. The ICA in its new statutes held its first General Assembly in 1998 during the 16th Congress in Seattle where the by-laws of the new organization were adopted by the Member Societies.

The ICA today is a Scientific Associate of ICSU (International Council for Science, a non-governmental organization under UNESCO with a global membership of national scientific bodies (121 members) and international scientific unions (30 members) and an Affiliated Commission for both IUPAP and IUTAM, the International Unions for Pure and Applied Physics and Theoretical and Applied Mechanics.

In contrast to a Union, however, a Commission is considered to represent a kind of sub-science. In this respect acoustics is apparently a part of physics or mechanics. The consequence for acoustics world wide is well known: Acoustic departments and institutes are scattered in various schools and faculties. Coordination of our activities is sometimes difficult, calling for better support in academia as well as for the profession itself. Sometimes it is difficult to make our voice heard inside physics, engineering, biology and many of the other disciplines.

Following-up the initiatives started by the pioneering work of the past ICA presidents Gilles Daigle and Phil Nelson, a major objective of the ICA board is to get acoustics established in ICSU as its own scientific discipline covering more than physics and mechanics, thus forming its own Union. We think that there will be benefit for all people working in or with acoustics and vibration. This process, however, is very tedious and can be continued only in small steps, year by year. We, as the executive officers, will continue this discussion in ICSU.

The ICA has 44 national member societies from around the world and 6 International Affiliates (I-INCE, IIAV, ICU, EAA, FIA and WESPAC).

The Board 2011-2013 includes the executive officers, President Michael Vorländer (Germany), Secretary General Marion Burgess (Australia), Vice-President Charles Schmid (USA), Treasurer Antonio Perez-Lopez (Spain) and Past-President Samir Gerges (Brazil) and nine more board members representing the acoustical societies of Canada, China, France, Italy, Japan, Korea, Poland, Russia, and United Kingdom.

One of the main activities of the ICA is the organization of the International Conference on Acoustics (Sydney 2010, Madrid 2007, Kyoto 2004, etc.). But in between this triennial conference planning, the ICA commission sponsors specialized symposia, helps emerging acoustic societies in their foundation and coordinates the meeting calendar of acoustic events throughout the world. The ICA-sponsored conferences are normally limited to a specialized topic with an anticipated small attendance typically no more than 300. Supported are specialist regional meetings or national meetings, especially in developing regions, but only considered if the conference has an international character. The amount of financial support is mainly provided by the ICA to pay travel expenses for distinguished speakers, young scientists and especially for scientists from developing countries.

With these initiatives we are promoting international development and collaboration in all fields of acoustics including research, development, education, and standardisation.
All member societies are invited to distribute communications from the ICA to their members. And individual members in member societies may apply for any of the grants and awards offered by the ICA.

The world family of acoustics will meet again at ICA 2013 in June 2013 in Montreal, Canada. We are looking forward to visiting this beautiful city and to meeting there for discussing progress in acoustics.

Michael Vorländer

Aachen, Germany

President ICA 2011-2013

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# Adapting Simple Prediction Methods to Sound Transmission of Lightweight Foam Cored Panels

**K. O. Ballagh**

Marshall Day Acoustics, Auckland, New Zealand

*A paper previously presented at ISSA 2010, 29-31 August 2010, Auckland*

## Abstract

A common building product used in industrial buildings consists of thin steel or aluminium skins on each side of a foam plastic core such as polystyrene. Such panels have many attractive properties, they are light weight, have excellent capacity to span between structural supports, excellent thermal insulation and are pre-finished. They are used extensively in many countries, and in New Zealand these types of panels are commonly used in food processing plants which are often noisy and located close to residences. The sound transmission loss of these panels in their basic form is poor, usually less worse than a simple mass law prediction based on the mass of the components. The performance is characterised by a sharp dip in the sound transmission loss at mid frequencies which causes a big drop in $R_w$ or STC rating. The work described in this paper has developed simple methods of predicting the sound transmission loss of panels both as single panels and more importantly when used as part of a system to achieve higher performance.

## Introduction

Lightweight steel panels with a foam core are widely used in the building industry throughout the world. They usually consist of steel skins about 0.5 – 1.0mm thick, with a core of foamed plastic about 50 – 200mm thick. The foam core is often expanded polystyrene (EPS) but other materials such as foamed polyurethane are also used.

These panels have a number of very useful constructional properties including their lightweight, ability to span long distances, the fact they have a high quality pre-finish, and their excellent thermal insulation properties. In New Zealand they are widely used for the construction of food processing plants and coolstores.

However, the sound insulation properties are often inadequate when used for exterior cladding of noisy factories. Alternative construction options such as pre-cast concrete have weighted sound transmission ratings ($R_w$) of greater than 45 dB. By contrast typical foam cored panels can have weight sound transmission ratings of around 20 dB, significantly less than would be expected from a simple estimate based on the mass law. Single panels of equivalent mass (e.g. gypsum board) have a rating of 28 dB. This paper will examine the reasons for this and propose a relatively simple method of predicting the performance of such panels both when used as single panels, and as part of more complex constructions.

## Sound Transmission Of Single Panels

The measured performance of foam cored panels is quite distinctive, an example is shown in fig 1. At low frequencies the transmission loss increases at 6 dB per octave up to a frequency around 600-800 Hz, where it dips sharply around 1-2 kHz to a value often lower than its value at low frequencies, then increases sharply up to a value of around 40 dB from 2 – 5 kHz. Unfortunately the dip at around 1 kHz reduces the weighted sound transmission index ($R_w$) and in practice this dip usually occurs at an important frequency for determining the A-weighted sound reduction of industrial noise.

## Prediction Model

It is important to understand the reasons for the poor performance and to be able to predict the sound insulation of such panels. Initial investigation explored the possibility that this was a critical frequency dip, similar to the coincidence dip seen in most isotropic materials (e.g. gypsum board, concrete, glass, timber). However, the shape of the transmission loss versus frequency

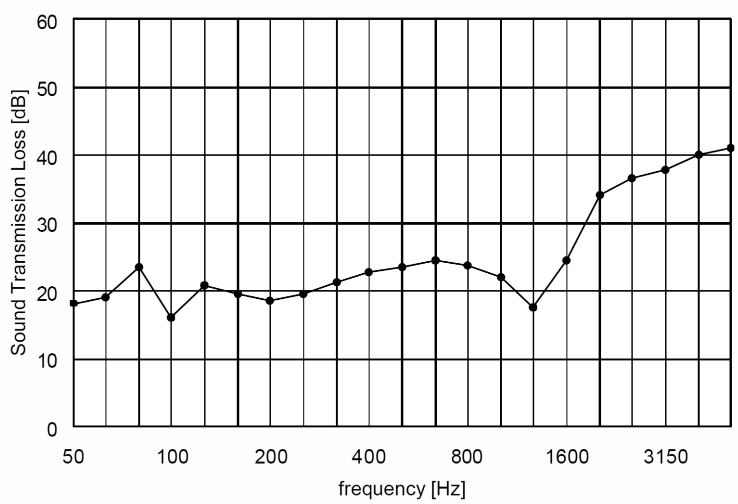



**Figure 1. Sound Transmission Loss of a typical foam core panel.**

curve was different to a classic critical frequency dip, and the frequency did not seem to be strongly related to the thickness of the panel. An alternative explanation [1] is that the dip is due to a dilatational resonance, or mass-spring-mass resonance. The steel facings are the masses and the foam core forms the spring. The resonance frequency is given by

$$f_o = \sqrt{\left(\frac{E(m_1+m_2)}{T m_1 m_2}\right)} \qquad (1)$$

where $E$ is the elastic modulus of the core, $T$ the thickness of the core, and $m_1$ and $m_2$ the surface masses of the skins. A calculation of the resonance frequency for the panel of fig. 1 indicated this was close to the measured dip in transmission loss curve. For 0.45mm steel skins, and 50mm EPS core the predicted resonance frequency was 1400 Hz, which is quite close to the dip in the transmission loss in the 1250 Hz band.

The hypothesis therefore was that the resonance behaviour of the mass-spring-mass system directly added to the transmission loss of the basic panel (viewed as a simple lumped mass). The increase in velocity of the outer skins due to the resonance is give by the transmissibility curve for a damped single degree of freedom system.

$$\Delta R = -10 Log\left[\frac{1+\left(2\xi\frac{f}{fn}\right)^2}{\left[1-\left(\frac{f}{fn}\right)^2\right]^2+\left(2\xi\frac{f}{fn}\right)^2}\right] \qquad (2)$$

The parameters are the natural frequency of the system $f_n$ and $\xi$ the fraction of critical damping.

A plot is given in fig 3 for seven panels. The panels ranged in core thickness from 50mm to 150mm, and skin thickness from 0.45mm to 0.75mm

In the figure the calculated mass law for the panel is subtracted from the measured transmission loss of the panel.

The results have been normalised or shifted in frequency so the peaks are all at the same relative frequency. It can be seen that all panels exhibit a very similar behaviour. A theoretical curve is shown dotted for the response of a simple mass-spring-mass oscillator, with a resonance frequency the same as the normalised peak and with a fraction of critical damping of 0.08.

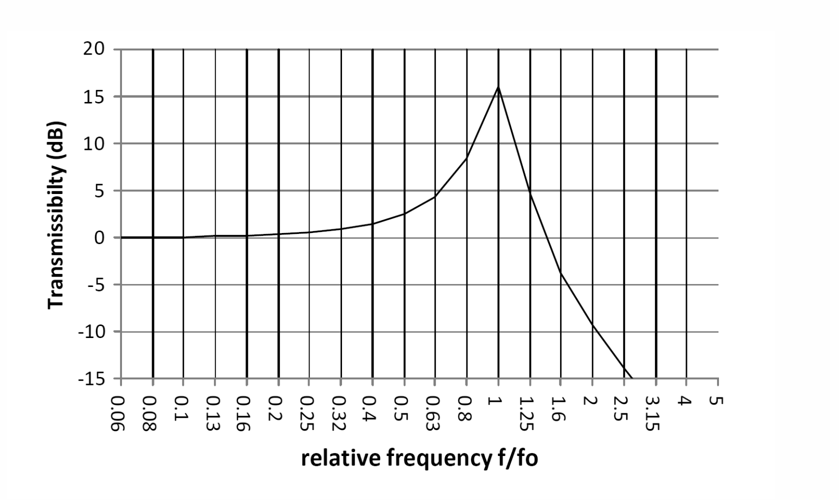



**Figure 2. Transmissibility of a damped mass spring mass system.**

The theoretical curve is very similar to the measured results. However, there seems to be a plateau in performance above the resonant frequency of between -5 to 5 dB. These results indicate that the mass-spring-mass behaviour is the cause of the dip and subsequent rise in transmission loss at high frequencies. A simple method of prediction therefore would be to use the mass law to predict a base performance of the panel and then subtract the transmissibility curve (equation 2) of a simple mass-spring-mass oscillator.

## Results

As an example a prediction has been made for a panel consisting of 13mm thick gypsum plaster board skins with a 64 mm thick EPS core. The comparison between measured and predicted results is shown in fig 4. The frequency of the dip was calculated from the mass of the skins and the thickness and elastic modulus of the EPS core. Allowance was made in the prediction of the base performance for the critical frequency of the gypsum board [2]. It can be seen that the agreement is good, with the dip at 3.15 kHz due to the critical frequency of the gypsum board. The measured weighted sound insulation (Rw) was 31 dB compared to the predicted 30 dB.

The model can be used to explore ways of improving the performance of foam core products. However it quickly becomes apparent that it is difficult to avoid the deleterious effect of the mass-spring-mass resonance. To move the dip either above or below the normal building acoustical frequency range of 100 – 4,000 Hz would require a very large change in parameters. For instance, increasing the thickness of the core by a factor of 100, or decreasing it by a factor of 20. Likewise, changing the skin surface masses by similar factors. These changes are clearly impractical.

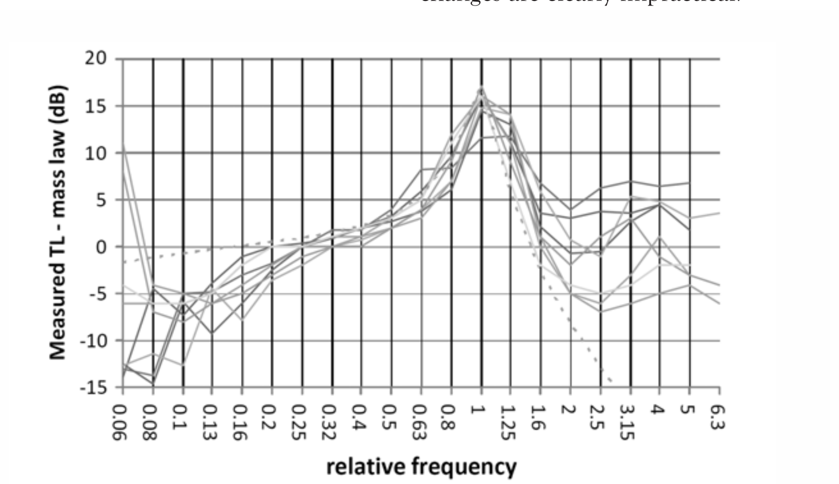



**Figure 3. Calculated mass law minus measured transmission loss for 7 different foam core panels.**

Alternatively the foam core panel can be used as a component in a multipanel system. The prediction model can be extended to double panel systems, where two panels (one or both of which are foam cored), are separated with an airgap.

Simple models are available for predicting double panel systems either with or without mechanical connections between the panels [3]. Foam cored panels can be handled by using these methods for equivalent isotropic panels, and then adding the effect of the mass-spring-mass resonance.

The double panel prediction models require the point impedance of the panel, and for a foam cored panel this has been assumed to be the point impedance of one skin.

So with a relatively trivial addition the well established prediction methods can be extended to include foam cored panels.

A comparison is given in fig. 5 of the measured and predicted sound transmission loss of a double panel system consisting of a 60mm thick steel faced, foam cored panel, fixed to one side of 100mm wide steel studs, with a 12.5mm thick gypsum board fixed to the other side of the steel studs. The measured weighted sound insulation ($R_w$) was 41 dB compared to the predicted 38 dB. The agreement is acceptable for engineering purposes.

A second comparison is given for a system comprising foam cored panel 50mm thick with 0.6mm skins and a

*Continued on page 32*


FORMAN
BUILDING SYSTEMS
FOR YOUR TOTAL ACOUSTIC INSULATION NEEDS
Acoustop Noise Barriers
• Acoustop Acoustic Absorbers
• Acoustop Acoustic Barriers
• dBX Flexilagg pipe lagging
• dBX non PVC Noise Barriers
Nova Polyester Acoustic Insulation
• Novahush Acoustic Blanket
• Novahush Bafflestack
• Novahush Panel Absorber
Metal Ceiling Systems
• Renhurst Ceiling Systems
• I.C.E. Metal Acoustic Tiles
• Linear Coruline Perforated Metal Ceiling System
• ACS Linear Look Metal Ceiling Systems
• Lindner Metal Systems Acoustic Tiles
• Armstrong Metalworks Acoustic Tiles
Mineral Fibre Ceiling Systems
• Armstrong range of acoustic ceiling tiles
• Armstrong Ceiling Grid
Soft Fibre Ceiling Systems
• Eurocoustic range of acoustic ceiling tiles
• Parafon range of acoustic ceiling tiles
Basotect
• Open cell melamine acoustic foam
Rondo
• Quiet Stud Friction fitted acoustic wall system
• Ceiling Grid
www.forman.co.nz
0800 45 4000

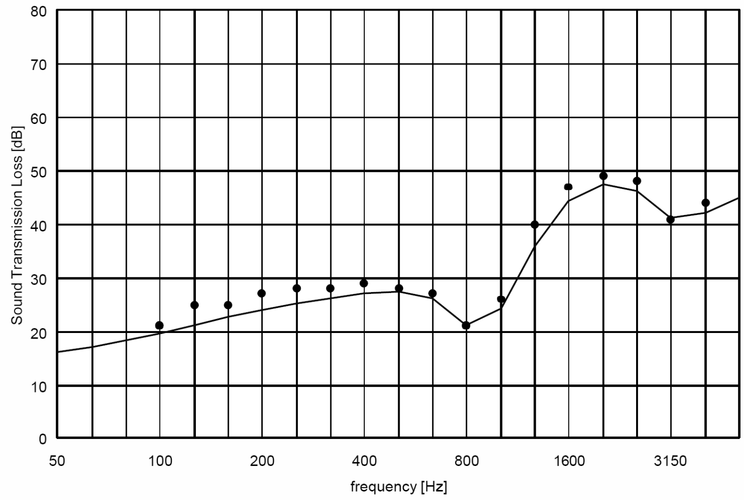



**Figure 4. Sound Transmission Loss of a panel with gypsum board skins and 64mm EPS core (• measured , — predicted).**

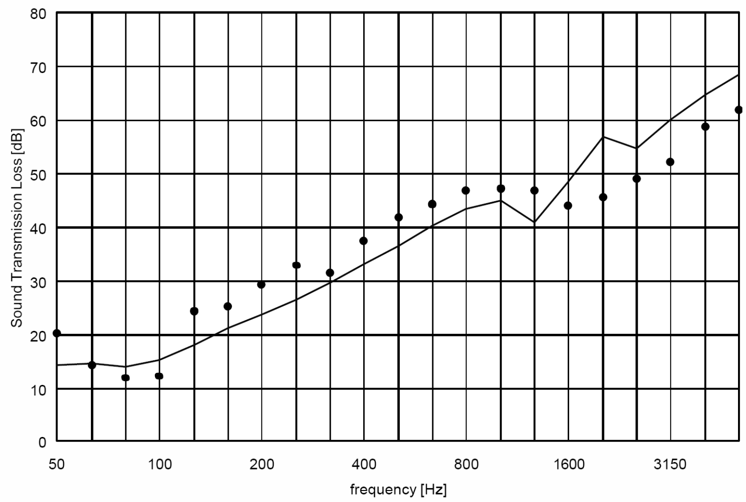



**Figure 5. Sound Transmission Loss of a foam core panel, air gap and gypsum panel. (• measured , — predicted).**

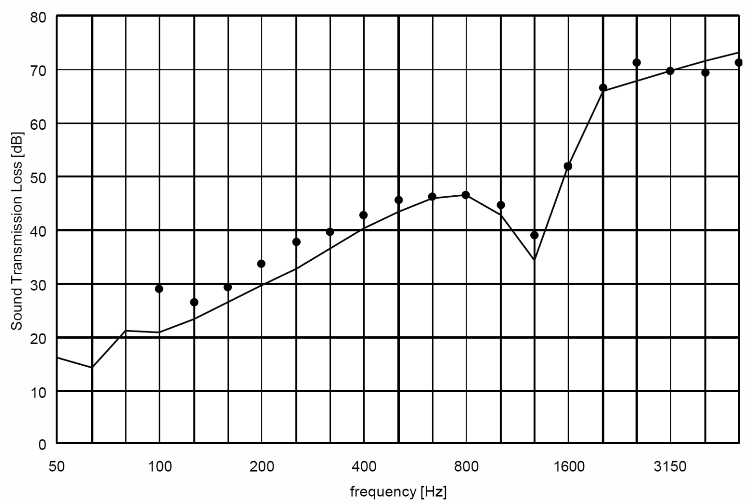



**Figure 6. Sound Transmission Loss of a foam core panel, air gap and foam core panel. (• measured , — predicted).**

*Continued from page 30*

layer of 12.5mm thick gypsum board in the centre, fixed either side of a 200mm airgap. No details of the frame that the panels were fixed to were available, so it was assumed to be a steel girt 300mm wide at 1200 mm centres.

Again the agreement between measured and predicted is acceptable, with measured $R_w$ 45 dB and predicted $R_w$ 42 dB.

## Conclusions

A simple method has been developed for predicting the sound transmission loss of lightweight foam cored panels.

Conventional prediction methods for isotropic panels are modified by adding on the transmissibility of a single degree of freedom resonant system. The method can be used for single panel constructions and for more complex constructions including double panel constructions with mechanical bridges between panels.

Three additional parameters are required, of which one can be calculated (resonance frequency) and the other two (damping and plateau level above resonance) must be found experimentally. Reasonable agreement is obtained between measured and predicted transmission loss for complex constructions.

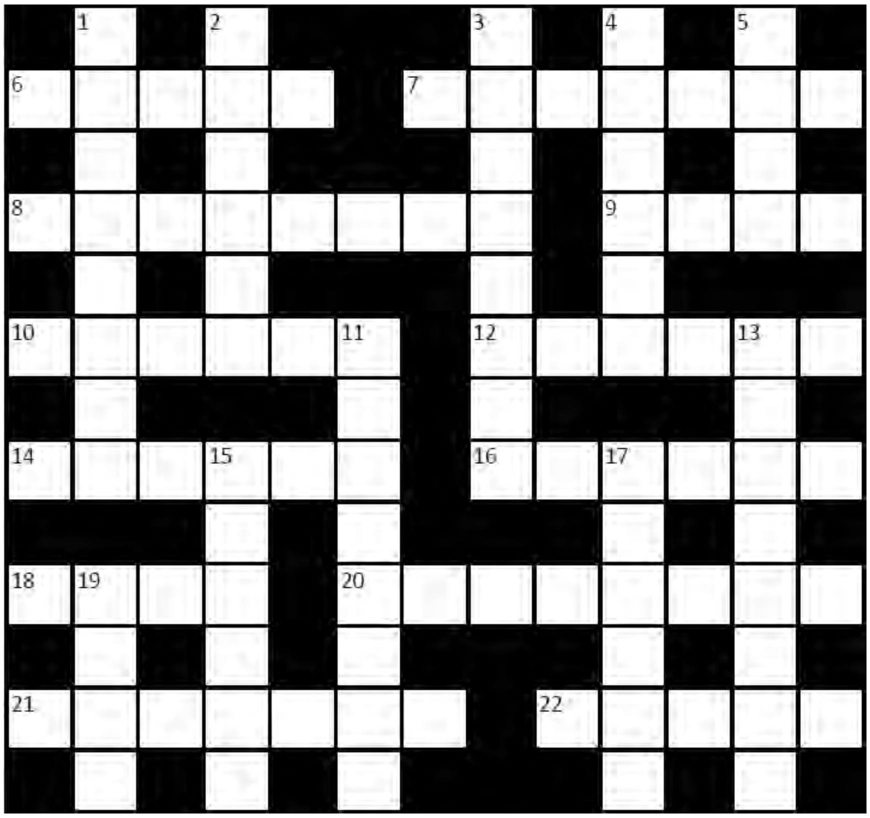
## References


[1] F.Fahy, Chap. 5 section 5.12 in "Sound and Structural Vibration Radiation, Transmission and Response", Academic Press, London, 1985.

[2] L. Cremer, "Theorie der Schälldammung dünner Wände bei Schrägen einfall", Akust. Ztg, 7, pp81 (1942).

[3] K.O.Ballagh, "Accuracy of Prediction Methods for Sound Transmission Loss", Proceedings of INTERNOISE 2004, paper in04_586, 2004.

# Acoustic Crossword #4




CLUES ACROSS

6. Express disdain audibly in one's coffee (5)
7. The lube ran around like a web (7)
8. Sounds like untruths after, or a method to hear how it will sound (8)
9. This kind of pipe will double the wavelength (4)
10. Point to the Maori language in both ears (6)
12. See 5 Down
14. Musical stress to speak with a difference (6)
16. Last night events show up on a scope (6)
18. Just one of 7 sings on the stage (4)
20. Orange County vessel worker resides within (8)
21. Unskilled percussionist tells a bad joke (7)
22. To catch a drum (5)

CLUES DOWN

1. What this Society is all about, without a point (8)
2. Not on ground nor heard on the radio (3,3)
3. About me with an X either side – must meet Section G6 (8)
4. The interrupting frequency (3,3)
5Dn, 12Ac. It keeps getting noisier in this place! (4,6)
11. Dunderhead not home around room resonance – no longer fashionable (8)
13. Note, thinner point for the housekeepers (8)
15. I sound the bell, and he calculates the RT (6)
17. I download it onto my iPhone, and attach it to the rear (6)
19. Pursue with no direction, it's how we communicate (4)

Crossword solution in the next issue.

*Crossword submitted by:*

*Calm Jokes with help from A Shy Mallard*

## Solutions to Crossword #3

Across:

2. Reverberating; 4.Stiffness; 7. LEQS; 9. Decibel; 12. DBA; 13. Tone; 14. Nyquist; 17. Mode; 19. Watt; 20. Ossicles; 21. PublicAddress

Down:

1.Vuvuzelas; 3. Insulated; 5. Impedance; 6. Ear; 8. SoundReduction; 10. Acoustic; 11. Attenuate; 15. Sound; 16. Haircell; 18. MassLaw

# Upcoming Events

## 2012

**20 -25 March, Kyoto, Japan. IEEE International Conference on Acoustics, Speech, and Signal Processing.**
http:// www.icassp2012.com

**13 - 18 May, Hong Kong, China. Joint meeting of the 183rd meeting of the Acoustical Society of America, 8th meeting of the Acoustical Society of China, 11th meeting of Western Pacific Acoustical Conference and Hong Kong Institute of Acoustics.**
http://acoustics2012hk.org

**2 - 6 July, Edinburgh, UK. 11th European Congress on Underwater Acoustics**
http://www.acua2012.com

**Internoise 2012**
**19 - 22 August, New York, N.Y., USA.**
Colleagues:

We hope you will join us at Internoise 2012 at the Marriott Marquis Hotel in New York City, USA, 19-22 August 2012. We are planning a large congress of over 1000 delegates, including:

- Three days of technical papers spanning many areas of noise and vibration, including our congress theme "Quieting the World's Cities™"
- A large vendor exposition (60+) of noise and vibration control materials, analysis software, and measurement systems and instrumentation
- Three plenary sessions on City Noise Codes, the Effects of Noise on Children, and Airport Noise
- A series of short courses on noise and vibration control

We will be issuing our call for abstracts (due 15 February 2012) shortly. In the meantime, please visit our website: www.internoise2012.com to learn more about what promises to be the premier vibration and acoustics conference of 2012.

Dr. Stephen A. Hambric

www.internoise2012.com

**19 - 24 August, Beijing, China. 23rd International Congress of Theoretical and Applied Mechanics (ICTAM2012).**
http://www.ictam2012.org/

**9 - 13 September. Portland, Or. USA. Interspeech 2012.**
http://interspeech2012.org

**12 -15 September, Granada, Spain. 30th European Conference on Acoustic Emission Testing (EWGAE) and 7th International Conference on Acoustic Emission (ICAE)**
http://2012.ewgae.eu/

**17 - 19 September, Leuven, Belgium. ISMA International Conference on Noise and Vibration Engineering (ISMA 2012).**
http://www.isma-isaac.be/conf/

## 2013

**26 - 31 March, Vancouver, Canada. 2013 IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)**
http://www.icassp2013.com

# CRAI Ratings

Despite my expectations to the contrary, it's been interestingly lately to find that when a group of diners of various ages rate the same venue, their ratings are very similar. On a recent outing in Christchurch, 6 people in the 45-60 age group gave an average rating of 2.9, while 4 people under 25 averaged 3.1. Nice to know it's not just us oldies who are annoyed by noise…

## Auckland

| | | |
|---|---|---|
| 215, Dominion Rd | (1) | ★★★★½ |
| Andrea (form. Positano), Mission Bay | (1) | ★★★ |
| Aubergine's, Albany | (1) | ★★★★½ |
| Backyard, Northcote | (1) | ★★ |
| Bask, Browns Bay | (1) | ★★★ |
| Bay (The), Waiake, North Shore | (1) | ★★★★★ |
| Bolero, Albany | (1) | ★★★★ |
| Bosco Verde, Epsom | (1) | ★★★★½ |
| Bouchon, Kingsland | (1) | ★★ |
| Bowman, Mt Eden | (1) | ★★★★½ |
| Bracs, Albany | (1) | ★★★★ |
| Brazil, Karangahape Rd | (1) | ★★★ |
| Buoy, Mission Bay | (2) | ★★★★½ |
| Byzantium, Ponsonby | (1) | ★★★ |
| Café Jazz, Remuera | (1) | ★★★★½ |
| Carriages Café, Kumeu | (1) | ★★★★ |
| Charlees, Howick | (1) | ★★★★★ |
| Cibo | (1) | ★★★★★ |
| Circus Circus, Mt Eden | (1) | ★★ |
| Cube, Devonport | (1) | ★★ |
| Del Fontaine, Mission Bay | (1) | ★★★★★ |
| Deli (The), Remuera | (1) | ★★★★ |
| Delicious, Grey Lynn | (1) | ★★★★★ |
| De Post, Mt Eden | (1) | ★★ |
| Dizengoff, Ponsonby Rd | (1) | ★★ |
| Drake, Freemans Bay (Function Room) | (1) | ★★ |
| Eiffel on Eden, Mt Eden | (1) | ★★ |
| Eve's Cafe, Westfield Albany | (1) | ★★★½ |
| Formosa Country Club Restaurant | (1) | ★★★★★ |
| Garrison Public House, Sylvia Park | (1) | ★★★★½ |
| Gee Gee's | (1) | ★★★ |
| Gero's, Mt Eden | (9) | ★★★ |
| Gina's Pizza & Pasta Bar | (1) | ★★★½ |
| Gouemon, Half Moon Bay | (1) | ★★ |
| Hardware Café, Titirangi | (1) | ★★★★★ |
| Hollywood Café, Westfield St Lukes | (1) | ★★½ |
| IL Piccolo | (1) | ★★★★ |
| Ima, Fort Street | (1) | ★★★★ |
| Jervois Steak House | (1) | ★★★ |
| Kashmir | (1) | ★★★★ |
| Khun Pun, Albany | (2) | ★★★★★ |
| Kings Garden Ctre Café, Western Springs | (1) | ★★ |
| La Tropezienne, Browns Bay | (1) | ★★ |
| Malaysia Satay Restaurant, Nth Shore | (1) | ★★★★★ |
| Mecca, Newmarket | (1) | ★★★★★ |
| Mexicali Fresh, Quay St | (1) | ★★ |
| Mezze Bar, Little High Street | (16) | ★★★★ |
| Monsoon Poon | (1) | ★★★★★ |
| Mozaike Café, Albany | (1) | ★★ |
| Narrow Table (The), Mairangi Bay | (1) | ★★★★½ |
| One Red Dog, Ponsonby | (1) | ★★★ |
| One Tree Grill | (1) | ★★★ |
| Orbit, Skytower | (2) | ★★★★ |
| Patriot, Devonport | (1) | ★★★½ |
| Pavia, Pakuranga | (1) | ★★★★★ |
| Prego, Ponsonby Rd | (2) | ★★ |
| Remuera Rm, Ellerslie Racecourse | (1) | ★★★★★ |
| Rhythm, Mairangi Bay | (1) | ★★ |
| Rice Queen, Newmarket | (12) | ★★★★ |
| Sails, Westhaven Marina | (2) | ★★★★★ |
| Scirocco, Browns Bay | (1) | ★★★ |
| Seagers, Oxford | (1) | ★★★★ |
| Shahi, Remuera | (1) | ★★★½ |
| Shamrock Cottage, Howick | (1) | ★★ |
| Sidart, Ponsonby | (1) | ★★★★½ |
| Sitting Duck, Westhaven | (1) | ★★★½ |
| Sorrento | (1) | ★★½ |
| Stephan's, Manukau | (1) | ★★★★★ |
| Tempters Café, Papakura | (1) | ★★★★★ |
| Thai Chef, Albany | (1) | ★★★★★ |
| Thai Chilli | (1) | ★★★★★ |
| Thai Corner, Rothesay Bay | (1) | ★★★★★ |
| Tony's, High St | (1) | ★★★ |
| Traffic Bar & Kitchen | (1) | ★★ |
| Umbria Café, Newmarket | (1) | ★★★★½ |
| Valentines, Wairau Rd | (1) | ★★★★★ |
| Vivace, High Street | (2) | ★★½ |
| Wagamama, Newmarket | (1) | ★★★★½ |
| Watermark, Devonport | (1) | ★★ |
| Woolshed, Clevedon | (1) | ★★½ |
| Zarbos, Newmarket | (1) | ★★ |
| Zavito, Mairangi Bay | (1) | ★★ ★ |

## Arthur's Pass

| | | |
|---|---|---|
| Arthur's Pass Cafe & Store | (1) | ★★★½ |
| Ned's Cafe, Springfield | (1) | ★★★★ |

**Readers are encouraged to rate eating establishments which they visit by completing a simple form available on-line from www.acoustics.ac.nz, or contact the Editor.**
**Repeat ratings on listed venues are encouraged.**

★ Lip-reading would be an advantage. ★★ Take earplugs at the very least. ★★★ Not too bad, particularly mid-week. ★★★★A nice quiet evening. ★★★★★The place to be and be heard. (n) indicates the number of ratings.

# CRAI Ratings (cont.)

## Ashburton

| | | |
|---|---|---|
| Ashburton Club & MSA | (1) | ★★★★½ |
| Robbies | (1) | ★★★ |
| RSA | (1) | ★★★★ |
| Tuscany Café & Bar | (1) | ★★★ |

## Bay of Plenty

| | | |
|---|---|---|
| Alimento, Tauranga | (1) | ★½ |
| Imbibe, Mt Maunganui | (1) | ★½ |
| Versailles Café, Tauranga | (2) | ★★ |

## Blenheim

| | | |
|---|---|---|
| Raupo Cafe | (1) | ★★ |

## Bulls

| | | |
|---|---|---|
| Mothered Goose Cafe, Deli, Vino | (1) | ★★ |

## Cambridge

| | | |
|---|---|---|
| GPO | (1) | ★★★★★ |

## Christchurch

| | | |
|---|---|---|
| 3 Cows, Kaiapoi | (1) | ★★★★ |
| Abes Bagel Shop, Mandeville St | (1) | ★★★★ |
| Addington Coffee Co-op | (4) | ★★★★ |
| Alchemy Café, Art Gallery | (1) | ★★★★★ |
| Anna's Café, Tower Junction | (1) | ★★★★ |
| Arashi | (1) | ★★ |
| Azure | (2) | ★★★ |
| Bamboozle, Sumner | (5) | ★★½ |
| Becks Southern Ale House | (11) | ★★★★½ |
| Buddha Stix, Riccarton | (1) | ★★★★ |
| Bully Haye's, Akaroa | (1) | ★★ |
| Cashmere Club | (1) | ★★★★★ |
| Christchurch Casino | (1) | ★★ |
| Christchurch Museum Café | (1) | ★★★★ |
| Cobb & Co, Bush Inn | (1) | ★★★ |
| Coffee House, Montreal Street | (1) | ★★ |
| Cookai | (3) | ★★½ |
| Corianders, Edgeware Road | (11) | ★★★ |
| Costas Taverna, Victoria Street | (1) | ★½ |
| Decadence Café, Victoria St | (1) | ★★★★★ |
| Drexels Breakfast Restaurant, City | (1) | ★★★★½ |
| Drexels Breakfast Restaurant, Riccarton | (1) | ★★★★ |
| Edisia, Addington | (1) | ★★★ |
| Elevate, Cashmere | (1) | ★★★ |
| Fava, St Martins | (1) | ★★ |
| Foo San, Upper Riccarton | (1) | ★★★½ |
| Fox & Ferrett, Riccarton | (1) | ★★★★★ |
| Freemans, Lyttleton | (9) | ★★★½ |
| Gloria Jean's, Rotheram St | (1) | ★★★★ |
| Golden Chimes | (1) | ★★★★★ |
| Governors Bay Hotel | (1) | ★★★★ |
| Green Turtle | (1) | ★★★★ |
| Harpers Café, Bealey Ave | (1) | ★★★★★ |
| Hari Krishna Café | (1) | ★★★ |
| Holy Smoke, Ferry Rd | (1) | ★★ |
| Indian Fendalton | (2) | ★★ |
| Joyful Chinese Rest., Colombo St | (1) | ★★★★★ |
| Kanniga's Thai | (1) | ★★★ |
| La Porchetta, Riccarton | (4) | ★★½ |
| Little India | (2) | ★★★★★ |
| Lone Star, Riccarton Road | (6) | ★★★ |
| Lotus Heart, Colombo Street | (1) | ★★★★ |
| Lyttleton Coffee Co, Lyttleton | (1) | ★★★★ |
| Manee Thai | (6) | ★★½ |
| Mexican Café | (6) | ★★★ |
| Myhanh, Church Corner | (4) | ★★★½ |
| Number 4, Merivale | (2) | ★★★★ |
| Oasis | (1) | ★★★★½ |
| Old Vicarage | (2) | ★★★½ |
| Phu Thai, Manchester Street | (1) | ★★★ |
| Portofino | (3) | ★★★★★ |
| Pukeko Junction, Leithfield | (1) | ★★★★ |
| Red, Beckenham Service Centre | (1) | ★★★★ |
| Red Elephant | (1) | ★★★★ |
| Retour | (1) | ★★★ |
| Riccarton Buffet | (2) | ★★★★½ |
| Robbies, Church Corner | (2) | ★★★★½ |
| Route 32, Cust | (1) | ★★★★ |
| Salt on the Pier, New Brighton | (6) | ★★★½ |
| Santorinis Greek Ouzeri | (1) | ★★ |
| Scarborough Fare | (1) | ★★ |
| Speights Ale House, Tower Junction | (1) | ★★★★ |
| Spice 'n' Life, Church Corner | (4) | ★★★★½ |
| Tap Room | (9) | ★★★ |
| The Bridge, Prebbleton | (1) | ★★★★★ |
| The Bicycle Thief | (1) | ★★★★½ |
| The Sand Bar, Ferrymead | (2) | ★★★½ |
| Tokyo Samurai | (1) | ★★★★★ |
| Tutto Bene, Merivale | (2) | ★★ |
| Untouched World Cafe | (1) | ★★★★★ |
| Wagamama, Oxford Terrace | (6) | ★★★ |
| Waitikiri Golf Club | (1) | ★★ |
| Waratah Café, Tai Tapu | (1) | ★★★ |

## Clyde

| | | |
|---|---|---|
| Old Post Office Cafe | (1) | ★★★★★ |

## Dunedin

| | | |
|---|---|---|
| A Cow Called Berta | (1) | ★★★½ |
| Albatross Centre Cafe | (1) | ★★★★★ |
| Bennu | (1) | ★★★★ |
| Bx Bistro | (1) | ★★★★ |
| Chrome | (1) | ★★★★½ |
| Conservatory, Corstophine House | (1) | ★★★★★ |
| Fitzroy Pub on the Park | (1) | ★★★★★ |
| High Tide | (2) | ★★ |

| | | |
|---|---|---|
| Nova | (1) | ★★★★★ |
| St Clair Saltwater Pool Cafe | (1) | ★★★★½ |
| Swell | (1) | ★★ |
| University of Otago Staff Club | (1) | ★★ |

### Feilding

| | | |
|---|---|---|
| Essence Cafe & Bar0 | (1) | ★★★★ |

### Gore

| | | |
|---|---|---|
| Old Post | (1) | ★★★ |
| The Moth, Mandeville | (1) | ★★★★★ |

### Greymouth

| | | |
|---|---|---|
| Cafe 124 | (1) | ★★★ |

### Hamilton

| | | |
|---|---|---|
| Embargo | (1) | ★★★★★ |
| Gengys | (1) | ★★ |
| Victoria Chinese Restaurant | (1) | ★★★★★ |

### Hanmer Springs

| | | |
|---|---|---|
| Laurels (The) | (2) | ★★★★★ |
| Saints | (1) | ★★★★½ |

### Hastings

| | | |
|---|---|---|
| Café Zigliotto | (1) | ★★★ |

### Havelock North

| | | |
|---|---|---|
| Rose & Shamrock | (1) | ★★★½ |

### Levin

| | | |
|---|---|---|
| Traffic Bar & Bistro | (1) | ★★ |

### Masterton

| | | |
|---|---|---|
| Java | (1) | ★★ |

### Matamata

| | | |
|---|---|---|
| Horse & Jockey | (1) | ★★★★★ |

### Methven

| | | |
|---|---|---|
| Ski Time | (2) | ★★★ |

### Napier

| | | |
|---|---|---|
| Boardwalk Beach Bar | (2) | ★★★★★ |
| Brecker's | (1) | ★★★★★ |
| Café Affair | (1) | ★★ |
| Cobb & Co | (1) | ★½ |
| Duke of Gloucester | (1) | ★★★★½ |
| East Pier | (1) | ★★ |
| Estuary Restaurant | (1) | ★★★★★ |
| Founder's Cafe | (1) | ★★★★★ |
| Napier RSA | (1) | ★★★★★ |
| Sappho & Heath | (1) | ★★ |

### Nelson/Marlborough

| | | |
|---|---|---|
| Allan Scott Winery | (1) | ★★★★★ |
| Amansi @ Le Brun | (1) | ★★★★★ |
| Baby G's, Nelson | (1) | ★★★★★ |
| Bouterreys, Richmond | (1) | ★★★★ |
| Café Affair, Nelson | (1) | ★★ |
| Café on Oxford, Richmond | (1) | ★★★ |
| Café Le Cup, Blenheim | (1) | ★★★ |
| Crusoe's, Stoke | (1) | ★★★ |
| Cruizies, Blenheim | (2) | ★★★★½ |
| Grape Escape, Richmond | (1) | ★★★★★ |
| Jester House, Tasman | (1) | ★★★★★ |
| L'Affaire Cafe, Nelson | (1) | ★★ |
| Liquid NZ, Nelson | (1) | ★½ |
| Lonestar, Nelson | (1) | ★★★★ |
| Marlborough Club, Blenheim | (1) | ★★ |
| Morrison St Café, Nelson | (1) | ★★½ |
| Oasis, Nelson | (1) | ★★★★★ |
| Rutherford Café & Bar, Nelson | (1) | ★★★★★ |
| Suter Cafe, Nelson | (1) | ★★ |
| Verdict, Nelson | (1) | ★★ |
| Waterfront Cafe & Bar, Nelson | (1) | ★★★ |
| Wholemeal Trading Co, Takaka | (1) | ★★★★★ |

### New Plymouth

| | | |
|---|---|---|
| Breakers Café & Bar | (1) | ★★★ |
| Centre City Food Court | (1) | ★★★★ |
| Elixer | (1) | ★★★★ |
| Empire Tea Rooms | (1) | ★★★★½ |
| Govett Brewster Cafe | (1) | ★★ |
| Marbles, Devon Hotel | (1) | ★★★ |
| Pankawalla | (1) | ★★★★★ |
| Simplicity | (1) | ★★★ |
| Stumble Inn, Merrilands | (1) | ★★★ |
| Yellow Café, Centre City | (1) | ★★★ |
| Zanziba Café & Bar | (1) | ★★★ |

### Oamaru

| | | |
|---|---|---|
| Riverstone Kitchen | (1) | ★★★★★ |
| Star & Garter | (1) | ★★★ |
| Woolstore Café | (1) | ★★★★ |

### Palmerston North

| | | |
|---|---|---|
| Café Brie | (1) | ★★★ |
| Café Esplanade | (2) | ★★★★ |
| Chinatown | (1) | ★★★★ |
| Coffee on the Terrace | (2) | ★★★ |
| Elm | (1) | ★★★★½ |
| Fishermans Table | (1) | ★★★★★ |
| Gallery | (3) | ★★★★ |
| Rendezvous | (1) | ★★½ |

# CRAI Ratings (cont.)

| | | |
|---|---|---|
| Roma Italian Restaurant | (1) | ★★★ |
| Rose & Crown | (1) | ★★ |
| Tastee | (1) | ★★★ |
| Thai House Express | (1) | ★★★★★ |
| Victoria Café | (1) | ★★★★ |

### Queenstown

| | | |
|---|---|---|
| Bunker | (1) | ★★★★ |
| The Cow | (1) | ★★★ |
| Sombreros | (1) | ★ |
| Tatler | (1) | ★★★★ |
| Winnies | (1) | ★★★★★ |

### Rotorua

| | | |
|---|---|---|
| Cableway Rest. at Skyline Skyrides | (1) | ★★★★★ |
| Lewishams | (1) | ★★★ |
| Woolly Bugger, Ngongotaha | (1) | ★★★ |
| Valentines | (1) | ★★★★★ |
| You and Me | (1) | ★★★★★ |
| Zanelli's | (1) | ★★ |

### Southland

| | | |
|---|---|---|
| Lumberjack Café, Owaka | (1) | ★★★★★ |
| Pavilion, Colac Bay | (1) | ★★ |
| Village Green, Invercargill | (1) | ★★★★★ |

### Taihape

| | | |
|---|---|---|
| Brown Sugar Café | (1) | ★★★★½ |

### Taupo

| | | |
|---|---|---|
| Burbury's Café | (1) | ★★★ |
| Thames | | |
| Thames Bakery | (1) | ★★★ |
| Waiheke Island | | |
| Cortado Espresso Bar | (1) | ★★★★ |
| Cats Tango, Onetangi Beach | (1) | ★★★★ |

### Timaru

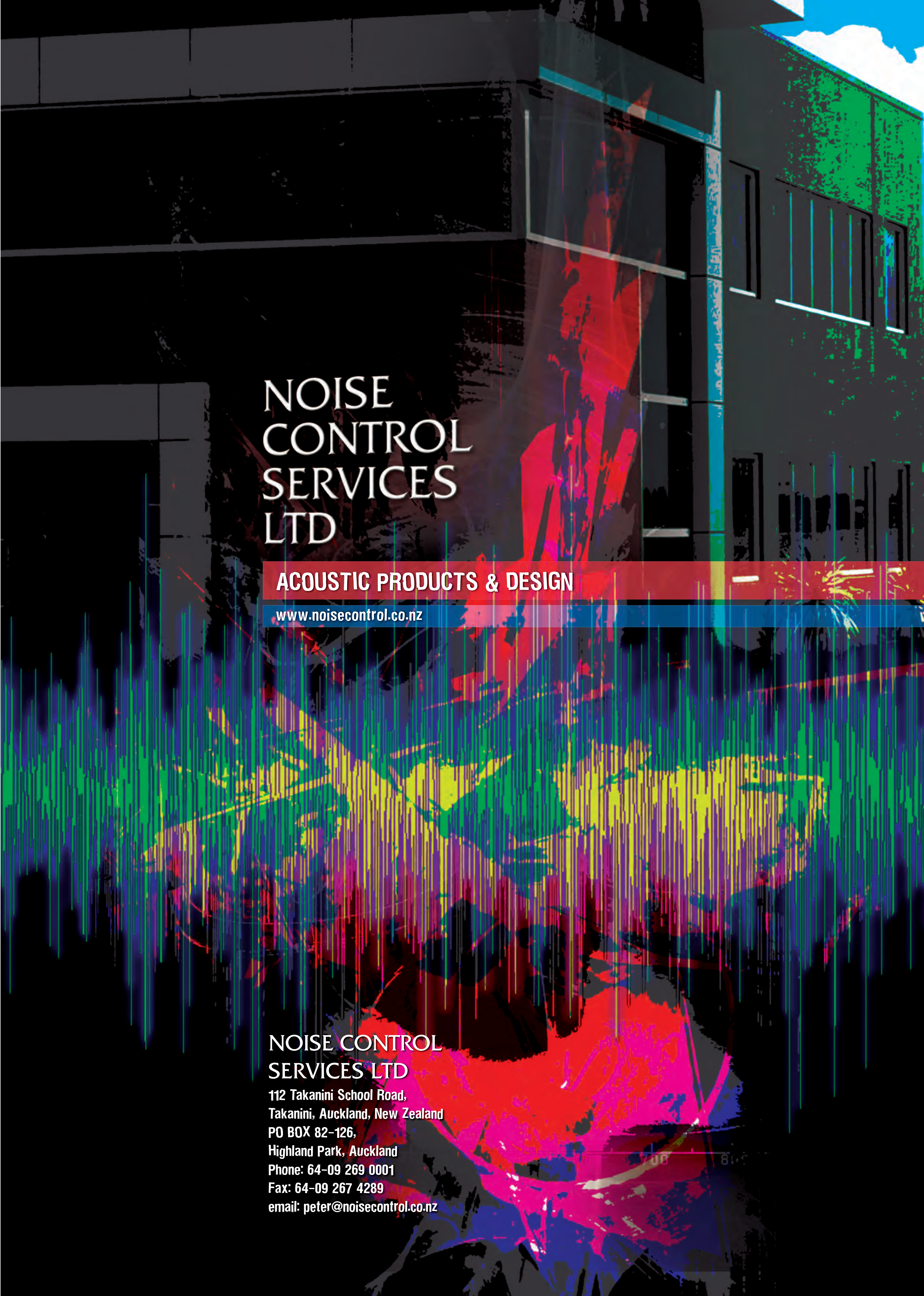
| | | |
|---|---|---|
| Fusion | (1) | ★★★★★ |

### Wanganui

| | | |
|---|---|---|
| 3 Amigos | (1) | ★★★½ |
| Bollywood Star | (1) | ★★★½ |
| Cosmopolitan Club | (1) | ★★★★ |
| Liffiton Castle | (1) | ★★½ |
| RSA | (1) | ★★★½ |
| Stellar | (1) | ★★★★½ |
| Wanganui East Club | (1) | ★★★★ |

### Wellington

| | | |
|---|---|---|
| 162 Café, Karori | (1) | ★★★★★ |
| 180o, Paraparaumu Beach | (1) | ★★ |
| 88, Tory Street | (35) | ★★ |
| Anise, Cuba Street | (1) | ★★ |
| Aranya's House | (1) | ★★★★★ |
| Arbitrageur | (2) | ★★★ |
| Arizona | (1) | ★★ |
| Astoria | (2) | ★★★ |
| Backbencher, Molesworth Street | (1) | ★★★ |
| Bordeaux Bakery, Thorndon Quay | (1) | ★★ |
| Brown Sugar, Otaki Railway Station | (1) | ★★★ |
| Buzz, Lower Hutt | (1) | ★★½ |
| Brewery Bar & Restaurant | (5) | ★★★★ |
| Carvery, Upper Hutt | (1) | ★★★★★ |
| Chow | (1) | ★½ |
| Cookies, Paraparumu Beach | (1) | ★★★½ |
| Cosa Nostra Italian Trattoria, Thorndon | (1) | ★★★★ |
| Gotham | (6) | ★★★½ |
| Great India, Manners Street | (2) | ★★★★★ |
| Habebie | (1) | ★★ |
| Harrisons Garden Centre, Peka Peka | (1) | ★★★★ |
| Hazel | (1) | ★★ |
| Katipo | (1) | ★★★★★ |
| Kilim, Petone | (4) | ★★★★½ |
| Kiss & Bake Up, Waikanae | (1) | ★★★ |
| La Casa Pasta | (1) | ★★★★½ |
| Lattitude 41 | (3) | ★★★★ |
| Legato | (1) | ★★ |
| Le Metropolitain | (1) | ★★★★★ |
| Loaded Hog | (5) | ★★★★½ |
| Manhatten, Oriental Bay | (1) | ★★★★ |
| Maria Pia's | (1) | ★★★ |
| Matterhorn | (1) | ★★★ |
| Mungavin Blues, Porirua | (1) | ★★★★★ |
| Olive Cafe | (1) | ★★★★★ |
| Olive Grove, Waikanae | (1) | ★★★½ |
| Original Thai, Island Bay | (1) | ★★★★ |
| Palace Café, Petone | (1) | ★★½ |
| Parade Café | (1) | ★★ |
| Pasha Café | (1) | ★★★★ |
| Penthouse Cinema Café | (2) | ★★★½ |
| Pod | (1) | ★★½ |
| Rose & Crown | (1) | ★★★★★ |
| Shed 5 | (1) | ★★ |
| Siem Reap | (1) | ★★ |
| Speak Easy, Petone | (1) | ★★ |
| Speights Ale House | (1) | ★★ |
| Sports Bar Café | (1) | ★★★★ |
| Stanley Road | (1) | ★★★ |
| Stephan's Country Rest., Te Horo | (1) | ★★★★★ |
| Wakefields (West Plaza Hotel) | (1) | ★★★ |
| Windmill Café & Bar, Brooklyn | (1) | ★★ |
| Yangtze Chinese | (1) | ★★★★½ |
| Zealandia Café, Karori Sanctuary | (1) | ★★★½ |



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CONTROL
SERVICES
LTD
ACOUSTIC PRODUCTS & DESIGN
www.noisecontrol.co.nz
NOISE CONTROL
SERVICES LTD
112 Takanini School Road,
Takanini, Auckland, New Zealand
PO BOX 82-126,
Highland Park, Auckland
Phone: 64-09 269 0001
Fax: 64-09 267 4289
email: peter@noisecontrol.co.nz