Technical considerations in evaluating environmental noise from entertainment venues

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Abstract - As our cities continue to develop more densely populated urban areas, amplified music from entertainment venues are considered in the context of residential amenity. Amplified music may be considered important to vibrancy and economic activity, but it is also a source of potential complaint to nearby residents. To provide certainty to stakeholders, some authorities have implemented planning and regulatory controls around environmental sound from entertainment venues and/or adjacent development. These controls define criteria and assessment methods in order to determine the acceptability of various proposals.

The challenge with these criteria and assessment methods are that they rely on various assumptions around measurement and prediction. Of particular interest to this study are issues which relate to low frequency sound and vibration effects. In this paper, we review some of the physical limitations and errors that can be expected, and provide recommendations for improvement. To reduce reliance on specialist expertise and increase the consistency of entertainment noise assessments, increased industry education and more specific methods of measurement and prediction are recommended.

1 INTRODUCTION

1.1 Background

Some Australian authorities including the Brisbane City Council, City of Perth and NSW government have implemented planning or regulatory controls concerning environmental noise from entertainment venues. These controls are presumed to be informed by sound pressure level measurements at positions that may be within or otherwise representative of sensitive areas. Figure 1 presents a conceptual sketch of measurement positions typically considered.

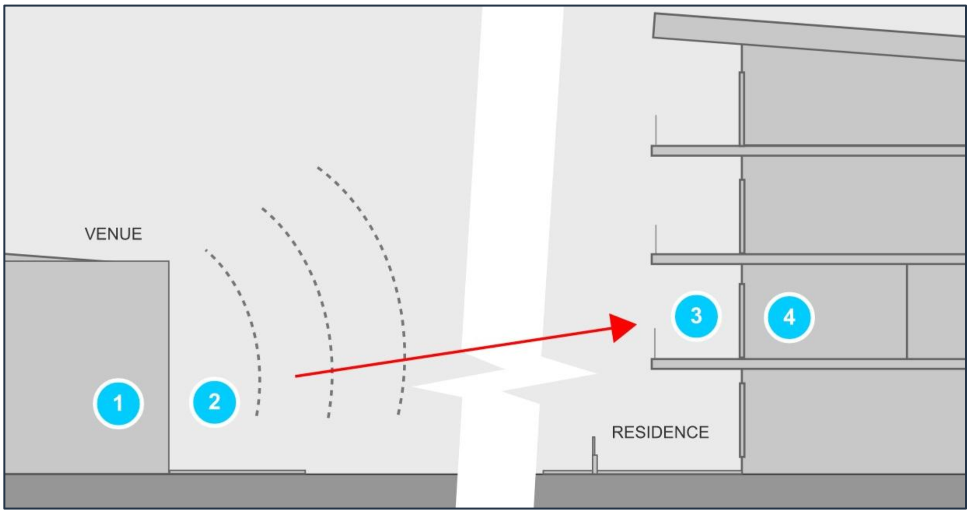

Figure 1 – Sketch of key conceptual measurement positions for assessing entertainment noise: (1) within the source, (2) immediately outside the source, (3) immediately outside the residence, and (4) within the residence.

1.2 Motivation

Music noise emissions are highly variable with time, which itself presents challenges around compliance assessments. Entertainment noise often includes amplified music, a common source of low frequency noise, here referred to as content in the third octave bands with centre frequencies ranging from 31.5 to 125 Hz. This paper is not considerate of specific limits or time-domain effects, or whether amplified music is itself undesirable. Rather, it considers the more basic difficulties of practical assessment at low frequencies.

Noting that field measurements in practice involve particularly more complicated environments than Figure 1, for the reasons discussed in this paper a high level of skill and judgement is needed. Section 10 of a guideline on preparing an acoustic report for QLD licenced venues (Office of Liquor and Gaming Regulation, 2020) states that a qualified, trained or experienced person is considered by the Commissioner to be

> “a person who has any of the following:
>
> - an appropriate tertiary or post-graduate qualification in engineering or science with a major in acoustics
>
> - successfully completed at least 2 modules of a professional education course in acoustics as supported by the Association of Australasian Acoustical Consultants or equivalent to a minimum of 5 years professional acoustical experience verified by a member of the Australian Acoustical Society.”

There is concern that relatively few experienced engineers and scientists are aware of low frequency sound propagation effects and the potential for measurement error compared to higher frequency content, especially within urban environments. Furthermore, specific techniques for measuring low frequency noise and accounting for likely ranges of error are not enshrined in relevant legislation.

Therefore, this paper discusses some of the risks associated with practically assessing low frequency music noise emissions in the context of an urban environment. The three key risks discussed here in regards to low frequency noise are errors associated with:

- Source characterisation;
- Predictions of transmission loss; and
- Room response effects.

2 SOURCE CHARACTERISATION

To work out the sound pressure level at different distances, the source needs to be described in terms of its sound power level. Ideally, the total sound power emitted from say a venue could be estimated by integrating the distribution in sound pressure level over imaginary three dimensional surfaces which encloses the venue or the vectors of interest. Unfortunately, this is impracticable given the scale and construction of most entertainment venues, so assumptions are often used to estimate a sound power level from a limited set of field measurements.

It is important to note that control measures are typically defined relative to the boundary, and not the building or any key spaces or openings such as courtyards. Consider a venue where key noise emissions from the premises are from upper levels, which may not be able to be sampled via a measurement near the boundary.

Assumptions that the venue exterior emits the same amount of noise evenly in all directions can be a critical source of error as this is not usually the case, especially with open windows or doors, or different building constructions.

Sound wavelengths in the 63 Hz octave band are around four to eight metres, so field measurements within a metre of an open doorway or side of a building would likely involve significant hydrodynamic and geometric near field effects (Bies, Hansen, Howard, & Hansen, 2024). Therefore, measurements immediately (within a couple of metres of) entertainment venues may be unreliable for the purposes of estimating sound power levels.

It is generally not recommended to measure sound pressure levels under these conditions and instead move further away to ‘free field’ conditions, where the methods described in various standards are more accurate in determining sound power levels. This is commonly impracticable in an urban environment, where diffuse fields can form up between parallel walls, resulting in almost negligible changes in outdoor low frequency sound levels between the venue and sensitive buildings across the street (indicated by Locations ‘2’ and ‘3’ in Figure 1).

3 PREDICTIONS OF TRANSMISSION LOSS

There are various prediction tools for estimating the transmission loss of glazing and various building façade elements, however there is concern that such tools and field data are lacking with respect to low frequency noise.

It has been noted by others (Gabriels Hearne Farrell, 2019) that relevant test standards for determining the sound reduction of building elements do not report values less than the third octave band with centre frequency 100 Hz, and test chambers are usually too small for the method to correctly indicate the in-situ level of performance. Accordingly, prediction tools which rely on laboratory data may not account for the effect of in-situ framing at low frequencies, leading to potential error in such predictions. Finite element modal analysis techniques would seem to be the only reliable desktop option for initial estimates.

At low frequencies, sound transmission loss is controlled by the stiffness of the panel (Bies, Hansen, Howard, & Hansen, 2024). Glass has a similar stiffness modulus to aluminium, but in 6 to 10 mm thick sections is considerably stiffer than the aluminium framing typically used to support it. Rubber gaskets and seals are also used between the glass and framing extrusions, reducing stiffness of support and allowing increased movement of the glazing.

The net effect of this is that at low frequencies, sound is not considered to be primarily transmitted by bending / flexing of the glazing, but via whole panes displacing out of plane back-and-forth like a ‘loudspeaker in reverse’. Therefore, the performance of glass framing systems (and their ability to restrain this glass pane movement) is critical to low frequency performance.

4 ROOM RESPONSE EFFECTS

Covering the frequencies from 44 to 88 Hz, the 63 Hz octave band includes sound wavelengths ranging from approximately four to eight metres. This is similar to or larger than the major dimensions of internal bedrooms and living spaces located near such venues. Accordingly, the number of resonant modes in each third octave band of interest are very low, leading to large and counterintuitive variations in sound level within the room.

For example, it may be measurably quieter near the window and openings closest to the noise source, with higher sound pressure levels on the opposite side, particularly in the corners and against the far wall, say where a bed is located. As a result, indoor measurements will vary considerably, substantially more so than free-field outdoor measurements. Controlled measurements undertaken by Pedersen et al (2007) identified scenarios where the difference in low frequency sound pressure level within a typical furnished bedroom can vary by more than 20 dB, and in some cases up to 30 dB. This was achieved in practice using third octave band content and hard floors.

In other words, it is feasible to consider that under some conditions, indoor measurements of music noise ingress within a metre of the window could be as much as 10 to 12 dB less than that actually experienced on a bed on the opposite side of the room in the 63 Hz octave band.

However, it is also reasonable to consider that in the absence of specific detail, the person undertaking the measurements (say in response to a concern or complaint) will not ignore positions which are louder and may in practice exclude quieter positions. They just need to be aware of the potential effects in advance. Standardising such methods would be required to ensure consistency.

5 TEST STUDY

To investigate the potential for low frequency room response effects as discussed in the previous section, a simple test was undertaken at a residential dwelling in Perth, Western Australia. A diagram of the test arrangement is shown in Figure 2. A loudspeaker located approximately 6 metres outside the dwelling produced a constant sound level incident on the facade to the front bedroom.

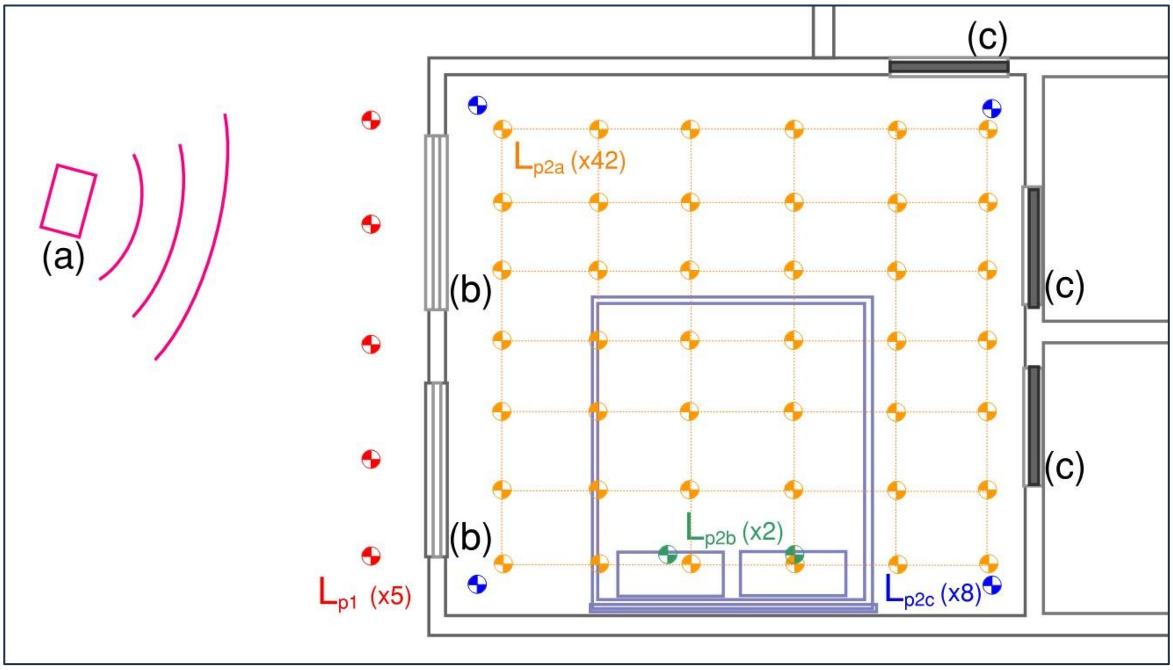

Figure 2 – Sketch of room arrangement: (a) loudspeaker; (b) uPVC awning windows; (c) internal doors.

This bedroom has three internal connecting doors, leading to an ensuite bathroom, walk in wardrobe and main corridor. Outdoor noise levels are normalised to the Northbridge Ambient Noise Spectrum (Gabriels Hearne Farrell, 2019), based on measurements of venues emitting content in this frequency range (Lloyd George Acoustics, 2019)

Selected properties of the bedroom are detailed further in Table 1. Selected results are presented in Table 2.

Table 1 – Test room properties

Parameter	Value
Width, d_x (m),	3.69
Length, d_y (m)	3.95
Height, d_z (m)	2.51
Temperature, (°C)	21
Furniture	Made up king size bed with fabric headboard, pillows, bedside tables, small wall shelf and freestanding tallboy
Window frames (x2)	uPVC coated steel, single awning plus fixed lower section
Glazing	6-12-6.38 mm double insulating units
Internal doors	Timber veneer doors, no seals fitted
Flooring	8 mm loop carpet, worn
External walls	Hard rendered double brick
Internal walls	Hard rendered single brick
Ceiling	Painted plasterboard with insulation over

A 6 x 7 grid of measurements were undertaken within the room area with 0.5 m spacings, at 1.5 m height above floor level, indicated with subscript ‘a’ in Figure 2. Two measurements were used to represent the two bed head positions here referred to as the ‘Bed’ measurements, indicated with subscript ‘b’. Measurements were also taken at 0.3 m distance from walls in each of the eight corners of the room, here referred to as the ‘Corner’ measurements, with subscript ‘c’. All measurements used a sample time of 15 seconds to minimise temporal effects. The internal doors were then opened, and the measurements repeated.

Table 2 – Selected results

Line	Aspect	Parameter	Third octave band centre frequency f_{tob}, Hz						
			40	50	63	80	100	125	160
1	Outdoors	Spatial average L_{p1}	78.4	86.5	85.1	81.5	76.9	74.3	71.1
2	Room modal response (doors closed)	Total modes	1	1	2	3	5	8	17
3		Axial	1	1	1	1	1	3	1
4		Tangential	0	0	1	2	3	3	9
5		Oblique	0	0	0	0	1	2	7
6	Internal doors open	Spatial average L_{p2a}	58.4	61.6	55.9	49.7	50.3	44.6	55.1
7		Max L_{p2a}	63.1	67.8	61.1	54.4	54.3	48.3	60.8
8		Min L_{p2a}	46.7	47.7	46.7	42.0	40.9	38.6	45.7
9		Median L_{p2a}	57.6	58.8	54.2	48.3	49.8	44.2	53.6
10		Difference L_{p2a}	16.4	20.1	14.4	12.4	13.4	9.7	15.1
11		Std dev. L_{p2a}	4.5	4.5	3.7	3.5	3.4	2.2	2.9
12		Bed average L_{p2b}	57.0	61.6	52.7	49.6	49.5	45.7	46.5
13		Corner average L_{p2c}	61.7	65.1	62.2	56.0	57.0	51.7	60.7
14	Internal doors closed	Spatial average L_{p2a}	52.3	65.3	56.9	49.1	55.5	48.4	53.6
15		Max L_{p2a}	58.6	71.6	62.9	53.8	60.4	52.9	59.5
16		Min L_{p2a}	42.4	57.5	49.3	41.5	42.5	41.1	44.2
17		Median L_{p2a}	51.4	64.0	55.1	48.1	54.8	48.0	52.3
18		Difference L_{p2a}	16.2	14.1	13.6	12.3	17.9	11.8	15.3
19		Std dev. L_{p2a}	4.2	3.4	3.7	3.2	3.8	2.7	3.4
20		Bed average L_{p2b}	53.0	64.1	53.8	49.1	54.1	47.8	45.7
21		Corner average L_{p2c}	56.0	69.1	63.0	55.9	62.5	54.2	60.3
22		Ambient sound level	37.8	38.3	39.4	31.9	30.4	29.1	28.5
23	Effect of closing the doors	Spatial average	6.2	-3.7	-1.1	0.7	-5.2	-3.8	1.5
24		Bed average	4.1	-2.5	-1.1	0.5	-4.7	-2.1	0.7
25		Corner average	5.7	-4.0	-0.8	0.1	-5.6	-2.5	0.4

From this table there are several notable results:

- The largest deviations and differences in spatial results were in the third octave bands with centre frequencies 40 and 50 Hz, in which there are only one axial room mode.
- The standard deviation in each low frequency third octave band result was at least 3 dB (Lines 11 and 19).
- The corner average results with doors closed (Line 21) provided reasonable gauge of the maximum room levels (Line 15), being within 3 dB of each result, aligning to studies by others (Pedersen, Møller, & Persson Waye, 2007).
- The measured levels at the bed head position (Lines 12 and 20) matched well with the spatial averages (Lines 6 and 14) at some of the third octave bands of interest, however not reliably so, cf. the third octave bands with centre frequencies 63 and 160 Hz.

- With the doors closed, the difference between the lowest and highest measured result ranged from 10 to 20 dB (Line 10). When the doors were opened, the differences narrowed to between 12 and 16 dB (Line 18).

Table 3 presents grid measurements of each third octave band result, to illustrate the differences in sound level across the room tested. From this table it is clear that low frequency effects are significant – for example, measurements of sound in the 63 Hz third octave band were 8 dB lower at the window facing the sound source than the room spatial average. Even in the third octave band with centre frequency 100 Hz, there were patterns where at multiple positions, one result was more than 9 dB different to adjacent positions 0.5 metres away.

A method which is based on measurements in the corners (noting progress by others in this area (Pedersen, Møller, & Persson Waye, 2007)) would appear to be the most robust towards assessing the spatial average noise level. However this would be less useful in informing what residents would actually experience in practice, due to the high variation in level within the room and that the specific listening positions are generally not in the corners.

Additionally, it can be seen that the position of the internal doors was significant in disturbing the internal distribution of sound levels, and this further complicates any efforts towards standardising such measurements in the field.

6 SUMMARY AND RECOMMENDATIONS

The prediction and measurement of entertainment noise containing low frequency noise within urban environments can involve substantive potential for error. This can lead to challenges around enforcement and consistency in application.

To reduce reliance on specialist expertise and increase consistency, increased industry education is recommended to

- increase awareness around the limitations of conventional measurement procedures, and
- standardise methods of measurement and prediction specific to the management of entertainment noise.

Table 3 – Individual Lp2a results less the spatial average Lp2a result, dB

f_{tob}, Hz	Doors closed						Doors open						Mode(s) (door closed)
40	4.6	1.2	-4.1	-11	-2.9	1.3	3.8	2.9	0.2	-6.5	-4.6	0.6	Axial (0,1,0)
	3.2	2.1	-3.5	-12	-5.9	0.5	3.2	2.1	-4.3	-8.4	-6.5	-1.4	
	2.0	0.7	-4.2	-11	-2.6	-1.8	2.4	0.3	-5.5	-7.9	-8.4	0.3	
	1.8	-1.3	-8.1	-8.0	-1.7	1.5	0.9	-2.5	-9.8	-3.4	-7.9	1.6	
	4.7	-1.0	-10	-4.1	1.1	2.0	-0.1	-3.1	-9.0	-0.2	-3.4	3.1	
	2.1	-2.2	-7.2	-3.4	1.1	3.0	0.4	-1.8	-6.5	1.6	-0.2	5.5	
	1.4	-0.6	-5.3	-0.6	1.3	4.2	-3.1	-4.5	-4.6	1.8	1.6	6.4	
50	-4.2	-2.3	-4.1	-7.5	-5.0	-2.8	-1.7	-2.1	-0.9	-1.7	0.3	-3.4	Axial (1,0,0)
	-3.4	-3.0	-4.0	-7.7	-3.0	-0.1	-5.1	-3.1	-3.7	-0.9	-0.9	-3.8	
	-	-0.8	-3.3	-12	-3.9	-0.2	-4.3	-5.7	-5.1	-0.4	-0.6	-1.2	
	2.0	1.5	-3.0	-14	-3.7	0.1	0.4	-2.5	-7.7	-1.6	-3.1	-	
	3.8	2.9	-0.5	-9.5	-4.5	1.1	2.5	0.8	-4.6	-0.9	-3.7	-0.1	
	4.8	4.5	1.1	-7.2	-3.9	0.6	5.7	3.9	-1.4	-1.5	-6.9	3.2	
	6.2	5.1	3.1	-5.5	-2.8	2.7	6.3	5.3	0.3	-0.7	-7.8	3.3	
63	4.1	4.7	1.9	-	1.4	2.1	4.5	3.9	0.9	2.8	-4.7	6.0	Tangential (1,1,0)
	0.8	1.9	1.8	-2.2	-0.5	5.2	2.9	1.6	0.5	1.6	0.3	3.9	Axial (0,0,1)
	-2.9	-0.5	-0.3	-3.3	-4.5	4.5	-0.7	-1.2	-2.3	-1.1	-0.9	-1.2	
	-8.2	-3.0	-2.5	-6.1	-9.2	0.1	-7.6	-5.6	-2.9	-4.1	-2.9	-4.2	
	-8.2	-7.0	-4.0	-5.2	-5.3	-1.3	-7.5	-6.3	-5.2	-4.2	-5.5	-2.1	
	-3.2	-5.1	-4.4	-3.7	-0.8	1.2	-2.6	-4.5	-6.2	-1.6	-5.9	3.4	
	-1.9	-2.9	-3.9	-1.6	2.1	5.0	-	-2.4	-4.7	1.4	-5.0	5.2	
80	-0.2	1.8	4.7	1.9	-3.2	-5.0	-1.3	2.1	4.7	-3.5	1.3	4.5	Tangential (0,1,1)
	-0.7	-0.5	2.6	0.3	-5.2	3.7	-3.9	-0.9	2.8	-3.3	0.5	3.3	Tangential (1,0,1)
	-1.5	-2.7	1.1	-1.5	-5.0	4.3	-4.7	-2.4	1.5	-3.2	0.2	1.9	Axial (0,2,0)
	-2.9	-6.2	-1.3	-2.5	-6.1	3.9	-4.3	-5.1	-0.1	-5.6	-1.2	1.8	
	-3.2	-6.6	-2.4	-3.6	-7.7	3.9	-2.8	-6.0	-1.9	-7.6	-4.6	1.7	
	-2.4	-3.1	-	-4.0	-7.0	3.3	-0.4	-3.4	-0.3	-4.9	-4.5	3.6	
	-0.8	0.2	2.2	-1.7	-5.0	4.1	0.1	-1.3	1.3	-2.3	-2.9	3.9	
100	-2.2	-5.8	-3.1	-4.8	-3.9	-5.3	1.7	-9.3	1.4	-5.1	-5.9	4.9	Axial (2,0,0)
	-7.0	-8.1	-3.8	-3.3	-4.3	4.0	-0.1	-7.8	2.0	-1.6	-2.2	2.9	Oblique (1,1,1)
	-1.2	-0.2	0.6	-	0.3	2.0	0.7	-1.8	2.9	-0.7	-0.4	1.7	Tangential (1,2,0)
	1.4	2.3	2.9	1.9	2.4	2.4	1.0	1.4	3.4	-0.8	0.3	0.6	Tangential (2,1,0)
	-0.9	-0.5	2.3	1.9	0.9	3.7	-4.0	-1.6	2.0	-3.7	1.3	-0.8	Tangential (0,2,1)
	-4.2	-9.4	-1.6	-0.5	-4.3	2.4	-2.1	-13	-1.8	-9.1	-1.0	-0.2	
	2.6	0.6	-2.0	-2.3	-5.3	1.1	3.5	-1.3	-5.9	-4.8	-1.5	2.1	

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