WHEN SOUND MATTERS

ACOUSTIC REPORT

NOISE ASSESSMENT OF EXTENDED TRADINGS FOR ON SUNSET RESTAURANT

2 RIVER RD, WEST PARRAMATTA NSW

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Acoustic Directions is a member of the Association of Australian Acoustical Consultants and our work is conducted in accordance with the Association's code of conduct.

1. INTRODUCTION

1.1. Overview

Acoustic Directions has been engaged by LJB Urban Planning to provide an acoustic assessment for the modification of development consent conditions in relation to trading hours and patron numbers in the outdoor terrace of the restaurant at 2 River Road West Parramatta, known as "On Sunset".

The development consent granted to the restaurant included a trial period of one year for outdoor dining with conditions pertaining to patron numbers and operational hours. At the conclusion of the one-year period, On Sunset's application to have the outdoor dining included in their consent conditions was refused by Council.

On Sunset is again seeking consent for the outdoor dining with the originally granted trial conditions as follows:

- 7am to 6pm – 48 patrons
  - Zone A under awning – 32 patrons
  - Zone B out in the open – 16 patrons
- 6pm to 10pm – maximum 24 patrons
  - Zone A under awning – 24 patrons
  - Zone B out in the open – Nil
- No music outside.

In addition, On Sunset is seeking permission to present live music inside the restaurant on Friday to Sunday between 10am to 6pm. The live music is not to include drum kits or strong percussion

1.2. Previous Work

In 2019, Acoustic Directions prepared an acoustic assessment for S4.55 pertaining to greater patron numbers and longer trading hours than listed above. To predict the total level of noise emitted from the restaurant, we undertook extensive measurements of sound transmission from the restaurant and combined that data with the results obtained with a mathematical model of the outdoor patron area. Those measurements and the acoustic model now form the basis of this assessment.

1.3. About Acoustic Directions

Acoustic Directions is a member firm of the Association of Australasian Acoustic Consultants (AAAC) and our Principal, Glenn Leembruggen, is a Fellow of the Institute of Acoustics, a Member of the Australian Acoustical Society and the Acoustical Society of America.

2. SITE DESCRIPTION

2.1. Site Details and Location

Following aspects are pertinent to our acoustic assessment:

a) On Sunset is located on the ground floor of a mixed-use development at 2 River Rd, West Parramatta. The restaurant premises includes an outdoor terrace, of which the majority is covered by a solid ceiling.

b) The terrace is provided to allow guests to dine and smoke.

c) Our observations and listening to noise produced by the current operation of On Sunset indicates that the most affected noise receivers will be the residence at 22 Noller Pde, Parramatta (R1) opposite On Sunset and residents of the apartment complex above On Sunset (R2 and R3).

d) The boundary of the residence at R1 is 25 m from the western façade of On Sunset.

e) The locations of these receivers are shown in Figure 1 and Figure 2 below.

f) Residents living in apartments directly above On Sunset will be sensitive to internal-to-internal noise transmission through structure-borne vibrations.

g) The internal and external areas of the restaurant are separated by floor to ceiling glazing.

h) The ceiling over the terrace forms an acoustic barrier for noise emanating from the terrace and propagating towards apartments above On Sunset. When viewed from above, the line of the terrace roof forms a division between Zone 1, which is the covered area and Zone 2, which is the uncovered area.

i) Works undertaken by On Sunset include the installation of ventilation louvres on the western side of the terrace. These louvres consist of fixed metal blades with a small inter-blade spacing and standard adjustable glass louvres.

j) On Sunset proposes to provide live music entertainment within the indoor area of the restaurant. Live music is expected to be performed by a single performer playing a keyboard and singing. As with all electronic keyboards, a percussion unit will be available to provide rhythmical accompaniment. Acoustic Directions understands that On Sunset's intention for live music is that it supports the atmosphere of the restaurant for patrons, but will not be sufficiently loud to interfere with patrons' conversations.

k) There are three doors within On Sunset that patrons can use:

- The main entry door on the western side of the restaurant is a hinged glass door.
- A hinged glass door on the northern side of the restaurant opens to the terrace to allow patrons and staff to move between the terrace and inside the restaurant.

Figure 1 and Figure 2 show the location of the subject site with the nearest residential receivers and measurement locations identified.

Figure 1. Site location, measurement location and worst-affected receivers identified.

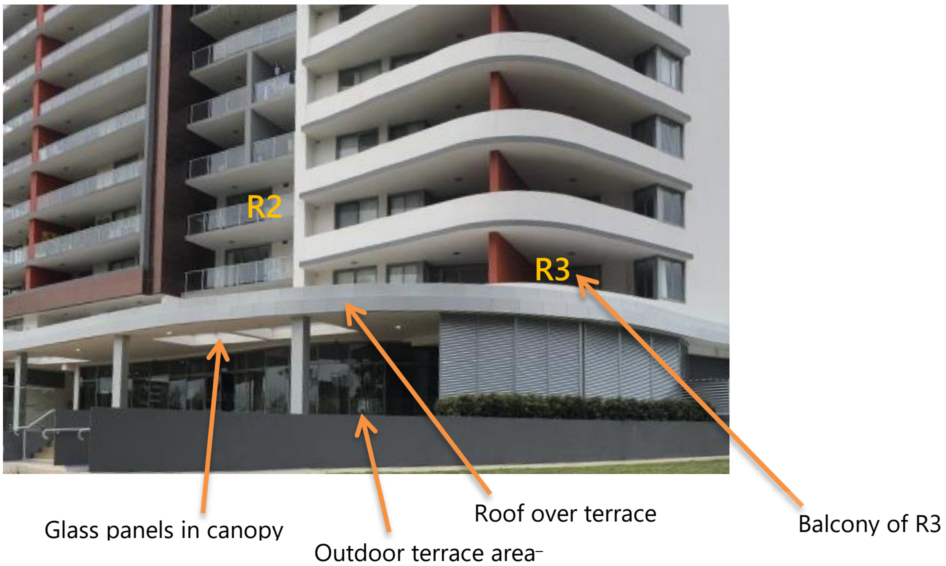


Figure 2. External view of On Sunset looking towards south-east.

3. BACKGROUND NOISE LEVELS

Long-term measurements of ambient noise levels were made in the rear yard of R1 (22 Noller Pde) to enable assessment of the impacts of operational noise on receivers. Noise levels were logged over a period of one week between 12:00 pm on Monday 8th July 2019 and 11:00 am on Tuesday 16th July 2019.

Although the background noise data was obtained in 2019, we consider that the data is still current, as there have been no major changes to the area and the vehicle numbers on surrounding roads.

The logger location is shown in Figure 1 above. At this location, the house at R1 provides considerable acoustic shielding of noise from vehicular traffic on River Rd West, Noller Pde and Alfred St.

The measurements were made using an NTI-Audio XL2 with a Class 1 measurement microphone. Calibration checks were done prior and after the logging to ensure the validity of data.

Using historical weather data at Parramatta from www.weatherzone.com.au, all levels associated with instances of inclement weather and wind speed greater than 5 m/s were removed from the logged data.

The logged data is presented in Appendix B.

From the measured L_{A90} data from the logger, the lowest $L_{A90\text{-}15\ minute}$ background noise levels were computed for a number of time periods pertaining to On Sunset's proposed trading hours. To provide a conservative measurement of the background noise, the minimum logged levels were used regardless of the day of week in which it occurred.

Table 1 below shows the lowest background noise level for each period calculated from the logged data.

Time Period	Day of minimum occurrence	L_{A90} level
7 am to 9 am	Monday	43 dBA
9 am to 6 pm	Monday	42 dBA
6 pm to 10 pm	Monday	41 dBA

Table 1. Existing lowest background noise levels at rear of 22 Noller Pde, Parramatta.

As it was not possible to access the balconies of the apartments above On Sunset, we were unable to measure the background noise levels at any apartments above the restaurant. However, on the basis that the logger location was relatively shielded from local traffic noise, we have assumed that the background noise level at balconies of apartments above On Sunset will be similar to that at the logger location.

4. NOISE CRITERIA

4.1. External Noise Receivers

On Sunset's Development Application (DA) Consent Conditions 41, 50 and 52 state: "The use of the premises shall not give rise to:

a) Transmission of unacceptable vibration to any place of different occupancy.

b) A sound pressure level measured at any point on the boundary of any affected residential premises that exceeds the background noise level by more than 5 dB(A). The source noise level shall be assessed as an LAeq,15 min and adjusted in accordance with Environment Protection Authority (EPA) guidelines for tonality, frequency weighting, impulsive characteristics, fluctuations, and temporal content as described in the NSW Environmental Planning & Assessment Act 1979: Environmental Noise Control Manual, Industrial Noise Policy 2000 and the Protection of the Environment Operations Act 1997."

Table 2 lists the adopted noise criteria for noise sensitive receivers. As the commercial premises C1 is not a residence, this receiver is not included in the assessment.

Time of day	Noise criterion $L_{Aeq\text{-}15\ min}$
7 am to 9 am	48 dBA
9 am to 6 pm	47 dBA
6 pm to 10 pm	46 dBA

Table 2. Adopted project noise criteria at noise-sensitive residential receiver locations.

4.2. Modifying Factor Corrections

Table 4.1 in the EPA's Industrial Nosie Policy specifies a number of adjustments or penalties that are to be applied to an intrusive noise if that noise contains specific characteristics. Those characteristics are listed in detail in that table and are:

- Tonality: specific frequency bands are higher than other bands by a defined amount
- Low frequency content: the C weighted level is more than 15 dB above the A-weighted level
- Impulsiveness: the difference between the levels with Fast and Impulse time constants exceeds 2 dB
- Intermittency: level varies by more than 5 dB

Penalties are 5 dB for each characteristic, with a total maximum penalty of 10 dB to be applied.

It is noted that when the intrusive noise is similar in level to the ambient noise and the ambient noise has impulsive characteristics such as occurs with traffic, it is virtually impossible to assess the impulsiveness of noise sources such as patron conversations and music.

4.3. Internal Noise Receivers

In an apartment that is very quiet, the ambient noise level in habitable rooms could be as low as 20 dBA. If noise from everyday sources such as refrigerators, air conditioning or external traffic (entering via open windows) is present in habitable rooms, the ambient noise level could be substantially higher than 20 dBA.

To prevent disturbance to residents who live in very quiet apartments directly above On Sunset, Acoustic Directions recommends that the level of noise from On Sunset inside apartments does not exceed 20 dBA. At this level, the noise will be inaudible above the ambient noise for most people. If the ambient noise is higher than 20 dBA in a habitable room, for example 25 dBA, the noise from the restaurant would be inaudible.

5. METHOD TO PREDICT NOISE EMISSIONS

A combination of acoustic measurements and modelling has been used to predict the noise levels reaching sensitive receivers for noise emitted from inside the restaurant and from the outdoor terrace. Each of these items is discussed below:

5.1. Noise Produced Inside the Restaurant

Sound escaping from the restaurant through the western glazed facade and door travels primarily in the forward direction towards R1, as the roof over the terrace and entry area provides an effective acoustic barrier for upward-travelling sound.

A. Patron Conversation Noise

An Acoustic Directions engineer measured the noise levels inside the restaurant on four occasions over two nights in which the restaurant was approximately 90% full. The engineer traversed the dining area producing a spatially-averaged L_{Aeq} level. The levels were averaged over the two nights yielding an average level of 75 dBA.

B. Music Noise

a) A test situation was set up in the restaurant in which a musician who sang and played keyboards performed songs to enable measurement of the levels outside the restaurant. The volume of the music was set by On Sunset management at a level that would provide the necessary atmosphere whilst still allowing comfortable conversation by patrons.

b) The Acoustic Directions' engineer made sound-level measurements inside the restaurant and outside the restaurant at defined distance from the restaurant's western façade. The western door of the restaurant was closed during the measurement.

c) An average level of 75 dBA inside the dining area was found to be a suitable level for music.

C. Combined Patron and Music Noise

Table 3 presents the spectrum in octave bands of the combined patron noise and music inside the restaurant.

	Octave Frequency Bands (Hz)									
	31	63	125	250	500	1000	2000	4000	8000	LAeq
Patron and music	50	75	81	77	79	74	68	62	55	79

Table 3. Combined spectrum of patron noise and music inside the restaurant, determined as a spatial average L_{eq}.

Using the measured relationship between inside and outside the restaurant, a calculation was made to predict the acoustic attenuation that noise from music and patrons undergoes as it travels from inside the restaurant to R1, via the western façade to the balcony of R3.

5.2. External Terrace Noise Prediction

The process to predict the noise levels at R1 and R2 used a combination of noise measurements, acoustic transfer measurements and a mathematical model of patron noise in the terrace.

In comparison to R1 and R2, Receiver R3 is much less affected by terrace noise, due to the greater attenuation of sound travelling from the terrace to R3 and therefore the level of terrace noise was not predicted at R3. Compliance with the noise criteria at R2 would ensure compliance at R3.

5.2.1 Noise Measurements

a) Measurements of the existing noise levels produced by On Sunset were made at the side boundary of R1 during trading periods on Friday 19th July 2019 and Friday 2nd August 2019 at approximately 9:30 pm. During these periods, approximately 65 patrons were seated in the outdoor terrace.

b) Measurements of noise from patron conversations were also made within the terrace area.

c) The measurements were made with an NTI XL2 sound level meter with a Class 1 microphone and enabled the accuracy of the acoustic model to be checked.

5.2.2 Acoustic Transfer Measurements to R1

a) The relationship between the sound levels in the terrace and Receivers R1 and R2 was measured using an acoustic transfer function analyser WinMLS2004 and a calibrated microphone.

b) A loudspeaker simulating a human talker was placed at three locations in the terrace with four orientations (N, S, E and W) and fed with the test signal from the analyser output.

c) Calibrated microphones were located at 1 m from the loudspeaker and also at R1 and their outputs fed back to the analyser input.

d) The analyser computed the difference between the level at 1 m from the loudspeaker and the level at R1. The average of the differences for each orientation was computed for each speaker location and used as an input to the acoustic model of the terrace described in Section 5.2.4.

5.2.3 Acoustic Transfer Measurements to R2

a) A similar process to Section 5.2.2 above was used the determine the acoustic relationship between sound levels in the terrace and levels reaching the balcony of R2.

b) An Acoustic Directions' engineer accessed the terrace roof via a long ladder and using a 5 m long pole, held the calibrated microphone approximately 500 mm from the edge of the balcony of R2, on Level 2 of the complex. This location would be more vulnerable to noise leakage from the terrace than the apartment below on Level 1, as upward-travelling sound would be subject to less acoustic shielding at R2 than on Level 1. Although the distance-loss of sound would be slightly greater at R2 than on Level 1, this would be offset by the reduced acoustic shielding at R2.

c) Two locations were used for the test loudspeaker to simulate different locations for the patrons on the terrace:

- Location 1 was under the terrace ceiling, 2 m from the outer edge of the terrace ceiling with the speaker aimed upwards towards that edge.
- Location 2 was in the uncovered area, 1.5 m from the outer edge of the terrace ceiling with the speaker aimed upwards towards the balcony at R2. At this position, the roof still provides some shielding, although it is substantially less than at Location 1.

5.2.4 Acoustic Modelling

The acoustic modelling process had two components:

- In Component 1, a prediction was made of the sound pressure level of a talker's vocal effort when the terrace has the patronage sought. That prediction accounted for the noise-creates-noise mechanism that occurs in restaurant terraces. This mechanism is discussed in Section 5.2.5.
- In Component 2, a specific number of talkers are each assigned a position in the terrace, and using the acoustic relationships between the terrace and R1 levels described in Section 5.2.2, the level at R1 was computed for each talker. The total level for all talkers in the terrace was then computed.

The accuracy of the model was confirmed using the measured noise levels described in Section 5.2.1.

5.2.5 Talker Levels and Spectra

We have employed the following method to predict the sound pressure levels produced by patrons occupying the outdoor terrace:

a) Sound pressure levels for an average male talker measured at 1 m were adjusted to account for the human response mechanism known as the Lombard effect. The Lombard Effect is responsible for the noise-creates-noise situations that often occur in restaurants, cafes, bars and social gatherings of people. The Lombard effect describes the process in which talkers in gatherings of people automatically increase their speaking level in response to the amount of ambient noise in the space in which they are talking, so that it will be easier for listeners to understand their speech.

Compounding the situation is the possibility of higher speech levels due to the effects of alcohol: Effects[1] of alcohol include overall improvement in mood and possible euphoria, increased self-confidence, increased sociability, decreased anxiety. These effects often produce more animated speaking styles, which often leads to elevated levels compared to a situation without alcohol. These effects have been accounted for in our calculated speech level spectrum.

b) This calculation model uses the following items:

- An algorithm to compute the speaking level of a talker for a given number of other talkers in the space and the acoustic environment in which they are speaking.
- A value of 0.5 was used for the Lombard ratio, which describes the increase in decibels of a talker's vocal effort for each 1 dB of increase in the background noise.
- One in two people are assumed to be talking.
- The directional nature of the human voice and the assumption that talkers are randomly orientated. Using these two parameters, an overall loss factor for sound from talkers travelling to receivers was developed at each frequency. The loss factors are incorporated into the calculated talker level.
- A minor amount of acoustic shielding that the human body provides as the sound from a talker propagates to a listener.
- Reverberation time at each frequency in the terrace in its current form and with proposed acoustic treatment.

c) Using the above parameters, the equivalent A-weighted and octave band sound pressure levels per talker were established and are presented in Table 4 below.

Source	Octave Frequency Bands (Hz)							L_{Aeq}
	125	250	500	1000	2000	4000	8000	
Single talker in terrace with 32 patrons under awing	48.2	57.8	60.4	56.0	49.7	44.2	37.7	61
Single talker in terrace with 24 patrons under awing	47.8	57.2	59.3	54.5	48.4	43.2	36.9	59

Table 4. Equivalent A-weighted and octave band pressure levels used to represent each talker in the acoustic calculation of noise emissions.

d) An important outcome of the model is that the noise levels within a speaking group increase by 6 dB for each doubling of patron numbers and not 3 dB as is commonly assumed.

e) The accuracy of the model was checked using the measured terrace sound pressure levels and patron numbers and the measured level at R1 and found to be within 1.5 dB.

5.3. Acoustic Design to Control Noise Levels

The combination of the internal noise level and the external noise level reaching Receiver R1 and R2 was computed using the acoustic model.

To bring the total noise level into compliance at 10 pm at R1, a number of changes were implemented in the acoustic model for the outdoor terrace:

- The western side of the terrace has a glazed wall that extends from floor to ceiling, and extending up to the ramp opening.
- The reverberation time in the terrace is reduced to approximately 0.2 seconds by the application of sound absorption panels over the entire ceiling of the terrace area.
- A limit is applied to the outer edge of the seating area after 10pm.

These items are described fully in the Section 7 Recommendations.

[1] From https://en.wikipedia.org/wiki/Short-term_effects_of_alcohol_consumption

5.4. Internal to Internal Noise Transmission

To calculate the level of noise that would be transmitted directly from within the restaurant to apartments directly above, the following process was used.

a) In Acoustic Logic's acoustic report of 10/12/2018 for On Sunset Reference 20181404.1/1012A/R1/JL, a measurement of the noise reduction between the restaurant internal area and Apartment 103 above is described. The process that was used appears to be correct and therefore the results appear credible. Table 4 of that report states the internal-to-internal noise reductions and is reproduced in Table 5 below.

	Octave Frequency Bands (Hz)								
	31	63	125	250	500	1000	2000	4000	8000
Noise reduction	43	43	56	57	65	67	67	68	70

Table 5. Noise reductions from inside the restaurant to inside Apartment 103 reproduced from Table 4 in Acoustic Logic report.

b) Using the spectrum of the combined music and patron noise inside the restaurant and the measured noise reductions, the level inside an apartment was calculated to be 16 dBA.

6. PREDICTED NOISE LEVELS

The following table (Table 6) lists the tables holding the predicted levels at receivers, compliance statements and the method used to calculate the result. As the noise from conversations is i) not tonal, ii) constant and iii) the music does not have strong low-frequency content, the modifying factors (i.e. penalty adjustments) do not apply in each instance.

Table No	Receiver No	Time period	Position	Prediction Method
Table 7	R1	7 am to 6 pm	boundary	acoustic modelling process described in Section 5.2
Table 8		6 pm to 10 pm		
Table 9	R2	7 am to 6 pm	balcony	
Table 10		6 pm to 10 pm		
Table 11	R3	7 am to 10 pm	balcony	process described in Section 5.1
Table 12	Inside apartment above internal restaurant area	7 am to midnight	internal	process described in Section 5.4

Table 6. List of Tables holding predicted levels, compliance statements and the method used to calculate the result.

Tables 7 to 11 below list the $L_{Aeq\text{-}15\ min}$ noise levels and the comparisons with adopted criteria for three receivers.

Time of day	Situation	R1 $L_{Aeq\text{-}15\ min}$	Criterion $L_{Aeq\text{-}15\ min}$	Compliance	Margin dB
7 am to 9 am	32 patrons under canopy	40 dBA	48 dBA	yes	8
9 am to 6 pm	16 in uncovered area		47 dBA	yes	7

Table 7. Calculated noise level for **R1** up to 6 pm with patrons in the covered and uncovered terrace areas.

Time of day	Situation	R1 $L_{Aeq\text{-}15\ min}$	Criterion $L_{Aeq\text{-}15\ min}$	Compliance	Margin dB
6 pm to 10 pm	24 patrons under canopy	33 dBA	46 dBA	yes	13

Table 8. Calculated noise level for **R1** with patrons in the covered terrace area only.

Time of day	Situation	R2 $L_{Aeq-15\ min}$	Criterion $L_{Aeq-15\ min}$	Compliance	Margin dB
7 am to 9 am	32 patrons under canopy 16 in uncovered area	46 dBA	48 dBA	yes	2
9 am to 6 pm			47 dBA	yes	1

Table 9. Calculated noise level for **R2** with patrons in both the covered and uncovered terrace areas.

Time of day	Situation	R2 $L_{Aeq-15\ min}$	Criterion $L_{Aeq-15\ min}$	Compliance	Margin dB
6 pm to 10 pm	24 patrons under canopy	38 dBA	46 dBA	yes	8

Table 10. Calculated noise level for **R2** with patrons in the covered terrace area only.

Time of day	Situation	R3 $L_{Aeq-15\ min}$	Criterion $L_{Aeq-15\ min}$	Compliance	Margin dB
7 am to 9 am	Internal area at full capacity 32 or 24 patrons under canopy	38 dBA	48 dBA	yes	10
9 am to 6 pm			47 dBA	yes	9
6 pm to 10 pm			46 dBA	yes	8

Table 11. Calculated noise level for **R3** with patrons in the restaurant and covered area.

Time of day	Situation	R2 $L_{Aeq-15\ min}$	Criterion $L_{Aeq-15\ min}$	Compliance	Margin dB
7 am to midnight	Full patronage inside restaurant with live music	16 dBA	20 dBA	yes	4

Table 12. Calculated noise level inside apartments directly above the restaurant with live music.

The above tables indicate that noise from On Sunset will comply with the external noise criteria with:

- 32 patrons seated in covered area and 16 patrons in the uncovered area up to 6 pm
- 24 patrons up to 10 pm.

7. RECOMMENDATIONS

The following recommendations are made to limit the level of noise reaching external and internal receivers.

7.1. Restaurant

a) Change the main restaurant entry door on Alfred St to an automatic sensor-operated sliding door.

b) Install a self-closing mechanism on the northern door between the restaurant and terrace.

c) The L_{Aeq} level of live music entertainment presented inside the restaurant should not exceed 72 dBA, when measured over the duration of any song in the patron seating area at a distance of 8 m in front of the loudspeakers that are used to amplify the performer(s). The C-weighted LC_{eq} level of the music should not exceed 80 dB when measured at the same position.

d) Live music performance should not include the use of a drum kit or strong percussive elements.

7.2. Terrace

a) Cover the entire ceiling of the terrace with sound absorption material. Two treatment options are available:

- Use 50 mm thick sound absorption panels that are suspended at least 50 mm below the ceiling so that an air space is provided above the panels. If required for aesthetics, the panels can be spaced apart by up to 150 mm. The panels shall have the sound absorption coefficients listed in Table 13.

  A suitable product is CSR Martini 50 mm dECO QUIET which is mounted in frames and suspended from the ceiling.
- Install 100 mm thick insulation directly against the terrace ceiling. The panels shall have the sound

absorption coefficients listed in Table 13. A suitable product is two layers of 50 mm dECO QUIET bonded together by the manufacturer.

- Both systems can be covered by a decorative fabric that is acoustically transparent.

Material	Octave Frequency Bands (Hz)						
	125	250	500	1000	2000	4000	8000
50 mm insulation with 50 mm gap to ceiling	0.35	0.80	1	1	1	1	0.9
100 mm insulation direct fix to soffit	0.6	1	1	1	1	1	0.9

Table 13. Recommended minimum sound absorption coefficients for suspended panels in terrace area.

The sound absorption material should extend to the edge of the terrace roof.

b) Glazing of 10 mm thickness should be installed on the western edge of the terrace and should extend from the floor to the slab above. In the region beyond the slab beside the entry ramp, the glass should be installed to the height of the slab above the terrace.

c) Figure 3 shows the areas in the terrace to be treated.

d) To allow the glazing described above to provide an acoustic barrier for sound travelling in a westerly direction, dining should not be allowed in the southern section of the southwestern part of the terrace as shown in Figure 3. To ensure that this requirement is not overlooked by staff, this no-dining area should be indicated by either either writing on the floor or a large sign on either of the two walls.

e) Long tables should not be allowed in the terrace or uncovered area, as long tables encourage loud conversations among large groups of people seated at these types of tables. Tables seating four patrons are recommended.

Figure 3. Acoustic treatments for terrace area and restaurant entry.

8. CONCLUSION

An assessment has been undertaken of the impact of noise resulting from the proposed extension of trading hours and patron numbers in relation to the outside terrace at On Sunset restaurant. The assessment has been based on a combination of acoustic measurements and modelling. Noise sensitive receivers have been identified within and beyond the mixed-use development in which On Sunset operates.

We conclude that if recommendations given in Section 7 for acoustic constructions and treatments and sound levels with live and background music are implemented, the level of noise reaching residents will comply with the noise conditions given in Council's DA consent.

9. APPENDIX A – GLOSSARY OF ACOUSTIC TERMS

9.1. Index to Terms

The glossary is arranged alphabetically to assist readers to find the required information by clicking on the link.

Assessment Background Level (ABL)

A-Weighted Sound Level dBA

Clarity Ratio

C-Weighted Sound Level dBC

Decibel (dB)

$D_{nT,w}$

Equivalent Continuous Sound Level (L_{eq})

Equivalent Acoustic Distance

Frequency Response

$L_{A1,}$(T)

$L_{A10,}$(T)

$L_{A90,}$(T)

Lmax,T - Maximum Sound Level

Rating Background Level (RBL)

Reverberation Time

Rw

Sound

Sound Absorption

Sound_Absorption_Coefficient

Sound Insulation

Sound Level Indices

Sound Power

Sound Pressure Level

Sound Reduction Index

STI

Vibration

Z- Weighted Sound Level dBZ

9.2. Glossary

SOUND

Sound is an instantaneous fluctuation in air pressure over the static ambient pressure, and is transmitted as a wave through air or solid structures.

SOUND PRESSURE LEVEL

Commonly known as "sound level", the sound pressure level in air is the sound pressure relative to a standard reference pressure of 20µPa (20x10-6 Pascals) when converted to a decibel scale.

DECIBEL (dB)

A scale for comparing the ratios of two quantities, including sound pressure and sound power.

The ratio of sound pressures which we can hear is a ratio of 106:1 (one million to one). To measure this huge range in pressure, a logarithmic measurement scale is used with the associated unit being the decibel (dB).

An increase or decrease of approximately 10 dB corresponds to an approximate subjective doubling or halving of the loudness of a sound. A change of 2 to 3 dB is subjectively a small change and may sometimes be difficult to perceive.

As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply to dB values.

The difference in level between two sounds s1 and s2 is given by 20 log10 (s1 / s2). The decibel can also be used to measure absolute quantities by specifying a reference value that fixes one point on the scale. For sound pressure, the reference value is 20µPa.

SOUND POWER

The sound power level (Lw) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (Lp) varies as a function of distance from a source or other factors such as shielding. However, the sound power level is an intrinsic characteristic of a source.

FREQUENCY

Frequency is the rate of repetition of a sound wave. The subjective equivalent of frequency in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to the number of cycles per second. A thousand hertz is often denoted kiloHertz (kHz), e.g. 2 kHz = 2000 Hz.

Human hearing ranges from approximately 20 Hz to 20 kHz.

OCTAVE BAND

The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the octave band below it. In subjective terms, it corresponds to a doubling of pitch.

For design purposes, the octave bands ranging from 31.5 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

A-WEIGHTED SOUND LEVEL dBA

The unit of sound level, weighted according to the A scale, which takes into account the increased sensitivity of the human ear at some frequencies. The unit is generally used for measuring environmental, traffic or industrial noise is the A weighted sound pressure level in decibels, denoted dBA.

A weighting is based on the frequency response of the human ear at moderate and low sound levels and has been found to correlate well with human subjective reactions to various sounds.

Sound level meters usually have an A-weighting filter network to allow direct measurement of A-weighted levels.

C-WEIGHTED SOUND LEVEL dBC

As the sound level increases, the ear is better able to hear low frequency sounds, The C-weighting filter allow low frequencies to contribute to the measurement much more than the A weighting filter.

Z-WEIGHTING dBZ

The Zero-weighting is equivalent of non-frequency shaping or weighting the measured sound level, and as no filter is applied to the sound before measurement, it is sometimes referred to as "linear" weighting.

SOUND LEVEL INDICES

Noise levels usually fluctuate over time, so it is often necessary to consider an average or statistical noise level. This can be done in several ways, so a number of different noise indices have been defined, according to how the averaging or statistics are carried out.

Examples of sound level indices are L_{eq},T Lmax, L_{90}, L_{10} and L_1, which are described below. The reference time period (T) is normally included, e.g. $dBL_{A10, 5min}$ or $dBLA_{90,8hr}$.

EQUIVALENT CONTINUOUS SOUND LEVEL (L_{eq})

Another index for assessment for overall noise level is the equivalent continuous sound level, L_{eq}. This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. This allows fluctuating sound levels to be described as a single figure level, which assists description, design and analysis.

The L_{eq} is often A-weighted to remove the contribution of low frequencies, which may be less audible and is written as L_{Aeq}. It can also have no weighting as L_{Zeq} or C-weighting as L_{Ceq}.

L_{max},T - MAXIMUM SOUND LEVEL

A noise level index defined as the maximum noise level during the measurement period duration T. L_{max} is sometimes used for the assessment of occasional loud noises, which may have little effect on the overall L_{eq} noise level but will still affect the noise environment. Unless described otherwise, it is measured using the 'fast' sound level meter response.

L_{90}(T)

A noise level index. The L_{A90} is the sound pressure level measured in dBA that is exceeded for 90% of the time over the measurement period T. In other words, the measured noise levels during the period were greater than this value for 90% of the measurement time period.

L_{90} can be considered to be the "average minimum" noise level and in its A weighted form is often used to describe the background noise a L_{A90}.

L_{A10}(T)

A noise level index. The L_{A10} is the sound pressure level measured in dBA that is exceeded for 10% of the time interval (T). In other words, the measured noise levels during the period were only greater than this value for 10% of the measurement time period.

This is often referred to as the average maximum noise level.

L_{A1}(T)

Refers to the sound pressure level measured in dBA, exceeded for 1% of the time interval (T). This is often used to represent the maximum noise level from a period of measurement, but is not the same as L_{Amax}.

RATING BACKGROUND LEVEL (RBL)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

ASSESSMENT BACKGROUND LEVEL (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background L_{A90} noise levels – i.e. the measured background noise is above the ABL 90% of the time.

Reverberation Time

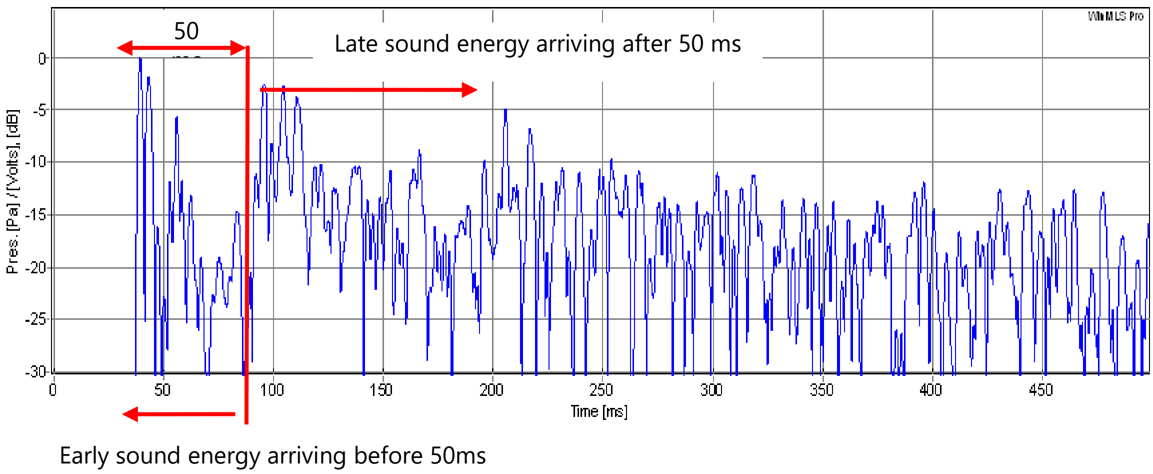
The time in seconds required for the sound at a given frequency to decay away (or reduce to) to one-thousandth of its initial steady-state value after the sound source has been stopped. This degree of reduction is equivalent to 60 decibels.

CLARITY RATIO

The clarity ratio is a metric that is used to assess the degradation in speech intelligibility due to the temporal effects of reverberation and echo. It is defined as the ratio of the sound energy of early-arriving sound that is useful for intelligibility to the energy of late-arriving sound which is not useful. Early-arriving sound consists of the direct sound and some reflections, while late arriving sound consists of reverberation and echoes.

Early-arriving sound consists of sound that arrives between the start of an extremely short pulse (an impulse) up to 50 ms after the start of the pulse, while late arriving sound is the total sound energy arriving later than 50 ms after the start of the pulse.

The following figure shows a typical impulse response and illustrates the dividing period of 50 ms between early and late arriving sound, which is used to compute the C_{50} clarity ratio.



Typical impulse response illustrating how the clarity ratio C_{50} is computed.

As the ear and therefore subjective intelligibility is sensitive to the amount of reverberation and echo at different frequencies, the C_{50} ratios must be as high as possible at all frequencies to maximise intelligibility.

STI - SPEECH TRANSMISSION INDEX

The Speech Transmission Index (STI) is one of the better available metrics to assess the capability of a transmission system to transmit intelligible speech. STI is a single number that ranges between 0 and 1. It attempts to assess the degradation in intelligibility caused by reverberation/echoes and background noise by measuring the reduction in modulation of the speech-like waveform. Phonemes in speech are produced by modulating vocal sounds in a specific pattern, and when perfect transmission of the modulation pattern is present at a listening location, the clarity is perfect. When modulations are corrupted by reverberation or noise, the time pattern of the phonemes is changed and the clarity is degraded.

However, STI has three fundamental weaknesses:

i) It is almost blind to the effects of tonal balance on intelligibility.

ii) It is partially blind to the effects of echo on intelligibility.

iii) It reduces many complex factors (frequency/level/time) into to a single number, thereby concealing important and audible components that contribute to the degradation of speech intelligibility.

To accommodate these weaknesses in STI, Acoustic Directions uses two other metrics (clarity ratios and frequency response) in conjunction with STI to assess speech intelligibility produced by a sound system.

The STI value is computed from weighted MTI values, which represent the loss of modulation in each octave-wide frequency range. When assessing STI performance, it is instructive to assess the loss of modulation in each frequency range by inspecting the associated MTI values.

Given that the majority of speech sounds occur in the 250 Hz and 500 Hz frequency ranges, the MTI values in these frequency ranges are a direct indicator of the smearing or degradation in vowel sounds. In turn, this indicates the extent to which long vowel sounds will subjectively mask sounds with higher frequency content such as consonants.

FREQUENCY RESPONSE

Subjective tonal balance is measured as a system's frequency response at each location. As the ear is very sensitive to the direct sound field (the first-arriving part of the sound before reflections arrive), the response of the direct field with speech must be as consistent as possible over the listening area in the frequency range of 100 Hz to 12 kHz.

EQUIVALENT ACOUSTIC DISTANCE

By amplifying a talker's speech, a sound system reduces the apparent acoustic distance between a talker and distant listener. The equivalent acoustic distance defines the resulting acoustic distance between the talker and listener and is a direct measure of the amount of voice amplification that the system can provide before the onset of acoustic feedback. Feedback is often heard as a strong colouration to the voice or howling sound.

We are accustomed to holding conversations in relatively close proximity, and to produce similar conditions in a courtroom and allow soft talkers to be heard, the EAD should be less than 2.2 m and typically 1.8 m without any trace of feedback or tonal ringing in the sound.

EAD is associated with speech intelligibility as it directly relates to the amount of speech amplification that the system can provide in order to deliver a satisfactory level of speech signal above the noise to each listener.

Factors affecting the EAD include:

- The number of microphones switched on at any time.
- The relationships between the directional response characteristics of the microphone and loudspeaker.
- The sound level reaching the audience at the critical mid and mid-high frequencies.
- Room acoustic behaviour.

VIBRATION

Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structure-borne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g. 1mms-1 or as a ratio on a logarithmic scale in decibels:

Vibration velocity level, LV (dB) = 20 log (V/Vref),

(where the preferred reference level, Vref, for vibration velocity = 10-9 m/s).

The decibel approach has advantages for manipulation and comparison of data.

SOUND ABSORPTION

This is the removal of sound energy from a room or area by conversion into heat.

SOUND ABSORPTION CO-EFFICIENT

Sound absorption co-efficient indicate the extent to which a material absorbs sound power at a specific frequency, and is expressed on a scale of 0 to 1, with a value of 1 representing the maximum possible absorption.

SOUND INSULATION

The sound insulation is the capacity of a structure such as a wall or floor to prevent sound from reaching a receiving location.

SOUND REDUCTION INDEX

This parameter is used to describe the sound insulation properties of a partition, and is the decibel ratio of the airborne sound power incident on the partition to the sound power transmitted by the partition and radiated on the other side. It is usually measured in specific frequency bands, such as octave or one-third octave.

$D_{nT,w}$

The single number quantity that characterises sound insulation between rooms over a range of frequencies with airborne sound.

R_w

Single number quantity that characterises the sound-insulating properties of a material or construction element over a range of frequencies with airborne sound.

10. APPENDIX B – NOISE LOGGER GRAPHS