Cost benefit analysis of acoustic treatments for inner-city residential premises near entertainment venues

David Borgeaud[1]

[1] Air Noise Environment Pty Ltd, Australia

ABSTRACT

Brisbane's Fortitude Valley is an inner city area combining retail, commercial, residential, and entertainment uses. For many years it has been the starting point for major Australian bands. The Valley's "Urban Renewal" has seen a large increase in the number of residential apartments, which has led to concerns regarding the impact this may have on the future of live music in the Valley. Brisbane City Council has developed entertainment precincts with specific noise criteria within the Valley (as part of the Valley Music Harmony Plan). Earlier papers by the Author addressed the ambient noise mapping and treatment of venues investigation, and this paper discusses the cost benefit study undertaken of acoustic treatment for existing residential premises. The purpose of this work was to provide Council with information on both the feasibility of treating the apartments to control low frequency noise and the order of cost for the treatments. The study found that attenuation of 2 – 16dB(C) could be achieved using a variety of site specific treatments with costs ranging from $34,000 to $64,000. The costing work proved an invaluable piece of knowledge in the implementation of the Valley Music Harmony Plan.

Keywords: Low frequency, Transmission, Residential I-INCE Classification of Subjects Number(s): 51.3

1. INTRODUCTION

Fortitude Valley is home to a wide range of uses, including live entertainment venues, residential development, retail facilities, commercial and industrial development. The introduction of residential apartments has raised concerns regarding the potential impact on the future of entertainment venues in the valley. To assist Brisbane City Council (BCC) in developing a suitable noise policy for Fortitude Valley it was necessary to understand the existing noise climate, the potential for control of music radiating from venues and the opportunity to control music entering residential apartments. Earlier papers by the author presented findings of studies involving noise mapping of Fortitude Valley to determine ambient noise contours (1) and a cost benefit study of the acoustic treatment of music venues (2). The Valley Music Harmony Plan (VMHP) was developed by BCC in consultation with the Liquor Licensing Division, Environmental Protection Agency, entertainment industry, and community stakeholders. In 2006 noise criteria and changes to Council (3, 4, 5), Liquor Licensing (6), and Building Code (7) documents were introduced as a result of the VMHP work. While these changes addressed venue noise and design of new residential apartment buildings, concerns were raised regarding the ability of existing apartments to attenuate amplified music. In particular low frequency music noise was of concern.

The author was engaged by BCC to undertake an investigation of the indicative costs (supply and installation) associated with retrofitting acoustic treatments into existing residential apartments. During the study information was gathered regarding factors that influence the degree of impact music noise has within residential apartments (eg. standing waves, hard finishes, furnishings), and practical steps that could be taken to minimise music noise impacts within the apartment (eg. installing a water feature or other masking noises).

1 david.borgeaud@ane.com.au

2. METHODOLOGY

Approach

An acoustic assessment was undertaken to allow the design of acoustic treatments, and appropriate sub-consultants were utilized to detail and estimate the cost of these treatments. The sub-consultants comprised an architect and a quantity surveyor. The apartments investigated had air conditioning (using split systems) and hence a mechanical services consultant was not used for this study. It was agreed with BCC that while there may be other issues associated with the cost of treating the buildings (eg. structural integrity, fire safety, heritage), the sub-consultants selected would have sufficient understanding of these issues for the costing exercise.

Selected Residential Premises

Brisbane City Council identified eight apartments for the study:

- Four apartments in the McWhirters Building, 38 Warner Street Fortitude Valley;
- One apartment in Fortitude Village, 27 Barlow Street, Fortitude Valley;
- Three apartments in the Sun Building, 351 Brunswick Street, Fortitude Valley.

These apartments have been built into the original heritage buildings. McWhirters and Sun Apartments both have open courtyards in the centre of the complex, while the apartment in Fortitude Village had an enclosed central atrium. The location of these apartment buildings in Fortitude Valley is shown in Figure 1.

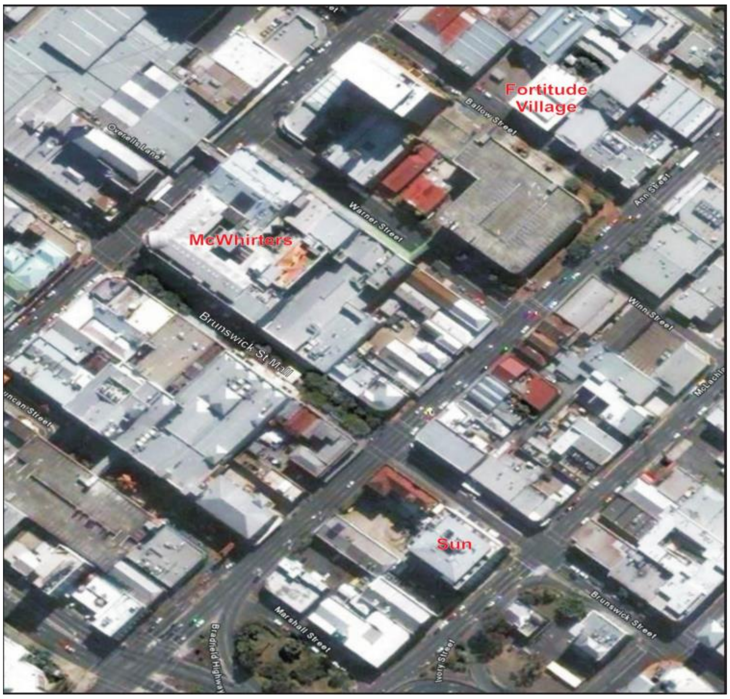

Figure 1 – Location of the three apartment buildings

These apartments gave a wide range of noise control options due to the different layouts and constructions of the apartments. While treatments were to be designed and costed for these eight apartments, the work was undertaken to provide generic solutions that would be applicable to a range of similar apartments.

The apartments were visited on two occasions in May and June 2006. Initially the author inspected the apartments to determine sufficient information regarding existing constructions to allow noise modelling to be undertaken, and then the author and the architect undertook a joint inspection to discuss the acoustic treatments.

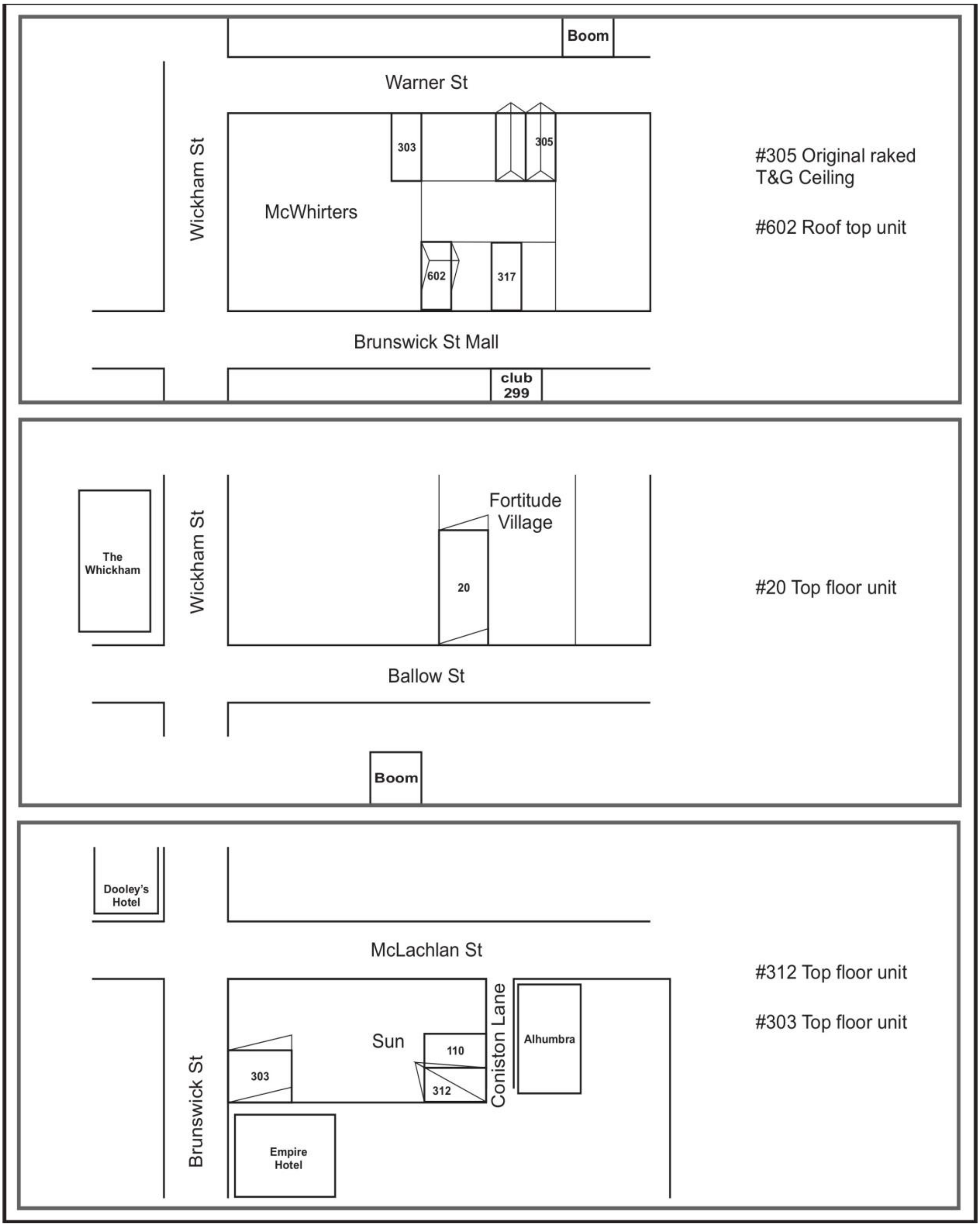

Figure 2 Location of the eight apartments within the three buildings

Design of Noise Attenuation Measures

The approach to the design of noise attenuation measures was to select various treatment options to reduce music levels inside the apartments. Treatments were grouped into three to four treatment options for each apartment, to provide increases in noise reduction with increasing complexity and cost. Noise levels inside the apartments with the existing constructions were modelled initially, and the internal noise level for each option was then modelled. The noise attenuation for each option was determined as the reduction in noise level compared to the predicted existing noise levels. The reported differences in noise reduction for the treatment options are indicative as validation measurements were not part of the scope of the study. The level of noise reduction achieved will vary from one apartment to another depending on a range of acoustic factors including: frequency content of the external noise, room shape and room modes, absorption within the room, sealing of elements into the building envelope, size of elements (eg. windows, doors) in the facade, flanking noise paths, and structure-borne noise.

The acoustic treatment options were modelled for one room, either bedroom, lounge room or in some cases combined lounge/ bed rooms (eg. #20 Fortitude Village, #602 McWhirters). During discussions with apartment occupants, it became apparent that music noise caused concern in both lounge rooms and bed rooms. Hence costs have been provided for lounge and bed rooms as appropriate as it was assumed that the owner would treat both rooms at the same time.

The approach to developing the options was generally as follows: treat roof first (usually weakest facade element acoustically), install heavier glazing, install double glazing, and finally install low frequency absorption modules. As a general note, it was found that the construction of the existing apartments utilised low cost constructions (eg. no roof insulation, external fibre cement sheeting 4.5mm thick). Laws in Queensland Australia, now require new residential premises to have thermal insulation installed (8) and this often provides additional acoustic performance for the building façade.

Modelling was undertaken using a combination of: test data for various window, door and roof/ceiling constructions, and estimated performance computed using transmission loss software for various materials to estimate the lower frequency performance where test data was not available. The effect of leakage of sound through the facade elements (eg. sliding windows) was included in the estimates, however this mainly effects the mid to high frequencies which are of less relevance to music from entertainment venues.

The music spectrum has been applied as the level experienced at the external façade of the building, and no allowance has been made for the effect of shielding from balustrades/parapets on verandahs. This decision was taken to make the results more generalized and less “unit specific”. Where only part of the roof would be exposed to the full external noise level, an allowance for shielding has been made (eg. the part of a pitched roof facing away from entertainment noise, or glazing/ doors to an internal courtyard, or roof parapet).

Design and Cost of Low Frequency Absorption Modules

Analysis of noise data provided by BCC showed that low frequency noise (centred on the 63Hz octave band) was the major component of audible music within the apartments. In small listening rooms such as in recording studios, it is common to use low frequency absorption devices to reduce unwanted low frequency noise within the space. Low frequency Helmholtz resonator type absorption modules were designed to provide maximum absorption at 63Hz (ie. the modules would be designed to peak at the desired frequency of 63Hz). These modules were preferred to “bass traps” (ie. using thick insulation in corners of the room) or unperforated panel absorbers, as the modules are expected to provide higher levels of absorption for the relevant frequencies than the other types of absorbers. A nominal design was discussed with an acoustic manufacturer and indicative costs provided. The nominal design for the modules was 900mm square x 250 - 300 deep, with perforated front panel. The modules would be suspended from the apartment ceiling. These modules would not be available “over the counter” and would need to be developed specifically for use in apartments to absorb the relevant frequencies in the 63Hz octave band. The costs discussed with the acoustic manufacturer included a nominal amount of $10,000 for research and development, plus a manufacture and install cost of around $500 per unit, plus an allowance for finishing/painting by the architect. The costs for the modules used in this report have been based on the sum of R&D, manufacture & installation, and finishing, divided by the total number of modules proposed for the 8 apartments selected for this study. Prior to making the modules available for purchase by the public, testing would need to be undertaken to confirm the ability of the modules to achieve an “audible” reduction in the low frequency noise within the apartment. That is to say, the expected reduction of around 3dB at 63Hz may be measurable with a sound level meter and audible to an acoustic engineer, but if the change in level is not apparent to the occupants, then the modules would not be a viable treatment option. The modules would be best installed in the corners of the room where practical, to maximise their effective absorption. During the site inspections, the architect felt that in some apartments it was not appropriate to allow for the installation of low frequency absorbers due to aesthetics/ space constraints or effect on heritage value of the space.

Music Spectrum

The external music spectrum used for design calculations was taken from noise data provided by BCC measured outside of the one of the Fortitude Valley venues. The data was selected as a bass dominated spectrum typically experienced by residential premises in the Valley, and was applied to all 8 apartments. The data provided by BCC was not sufficient to allow the transmission loss of the existing facades to be calculated, however measurements at one of the apartments in the Sun building confirmed again that 50Hz and 63Hz (1/3 octave bands) were the frequencies that most readily passed through the structure of the nightclub and the apartment facade.

The BCC noise criteria developed for the entertainment precincts are set in one-third octave bands from 31Hz to 125Hz. Hence it was desirable to provide low frequency noise attenuation data in addition to overall dB(A) and dB(C) data. However as discussed with BCC, acoustic test data for materials (eg. windows, facade sheeting) is typically only available down to 100Hz, with some field tests down to 50Hz, but very little data below this frequency. This is due to the difficulties associated with measuring low frequencies (long wavelengths) inside test chambers. Estimation of the performance at low frequencies where data was not available is more readily undertaken in octave bands. Analysis of the nightclub spectrum provided by BCC indicated that the majority of music energy entering the apartments was contained in the 63Hz octave band centre frequency, and that undertaking the analysis in octave bands from 63Hz to 8kHz would give representative results for the full music spectrum in dB(A) and dB(C). Hence is was agreed with BCC that the results would be provided for the 63Hz octave band, dB(A) and dB(C).

3. ACOUSTIC TREATMENTS AND COSTS

Inspections and Costing Decisions

Prior to the site inspection of the eight apartments, the author provided the architect with a list of the proposed acoustic treatment options. These treatments were reviewed and alternatives explored on site to develop the final treatment lists. The treatments were designed to provide practical solutions to reducing noise entering the apartments, taking into account cost effectiveness, heritage and functional requirements. For example, during inspection of the apartments, the architect felt that it was not appropriate to allow for the installation of low frequency absorbers in some spaces (eg. Sun #312 bed 1) due to aesthetics/ space constraints or effect on the heritage value of the space.

During inspection of the apartments, decisions were made to enable costing work to proceed in a consistent manner. The following points should be noted with regard to the indicative costs provided in this report:

- As with any renovation work, the scope of work can expand once work beings and unexpected items are discovered. However given the apartments are relatively new (built in the last 15years), the risk of unexpected issues was reduced;
- Costs assumed that the existing structure of the apartments could support the additional weight of the elements proposed, and hence no allowance was made in the costs for any structural work;
- Most of the apartments inspected have some heritage value as they are located inside heritage buildings. This may result in additional costs in selecting suitable materials, limitations on what works are allowed, and additional approvals required via BCC. Heritage was considered during design of the treatments, for example: heritage requirements limited replacement of ceilings to some apartments (eg. McWhirters #305), and replacement of glass to apartments (eg. McWhirters #317). However no separate heritage investigations were undertaken during the study;
- Costs do not allow for loss of rent for the owner, or cost of moving out while renovations are undertaken. The impact of works on neighbouring apartments may also need to be considered;
- The costs allowed for the acoustic treatment to be installed and making good of adjacent elements, however no allowance was made for possible consequential works (eg. repainting a whole wall or ceiling to match the new works);
- An allowance was made in the costs for relocation of lights and other fixtures;
- Changes to safety requirements for building works may result in higher costs for the suggested construction works where street closure and craneage is required. Street closure would be required where there was a risk that external works to the apartment may result in materials or tools being dropped onto pedestrians or vehicles on the footpath or street

below;

- Fire egress was considered in the architectural design of treatments, however no review by fire/ licensing authorities was undertaken as part of the study. Fire requirements may increase the costs provided;
- Openable windows were retained in the proposed treatments and the apartments have split system air conditioning units, hence the ventilation should be satisfactory. However no assessment has been made of the compliance of the existing systems with Building Code requirements.

Treatments and Costs

Table 1 provides a summary of the acoustic treatments, predicted attenuation and associated costs. A description of the apartment and summary of relevant existing constructions is provided for each apartment under the apartment number.

Treatments have been applied in a logical order from an acoustic perspective, however owners may choose a particular element that they feel is practical to treat. The Indicative Cumulative Noise Attenuation columns provide predicted 63Hz, dB(A) and dB(C) attenuation levels (a discussion of the relevance of these descriptors is provided in Section 2.5). The attenuation levels shown are cumulative, and the attenuation for individual treatments can be estimated by subtracting the attenuation achieved by the previous treatment.

The costs noted in Table 1 assume that the existing structure of the apartments can support the additional weight of the elements proposed, and hence no allowance has been made in the costs for any structural work. This includes: acoustic absorption modules hung from ceiling; additional layers of plasterboard applied to ceiling; glazing to walls; wall linings applied to walls. A structural check would be required prior to commencing any works.

Table 1 – Summary of Noise Attenuation and Costs for Apartment Acoustic Treatments

Apartment[1] & Option#	**Description of Acoustic Treatment[2]**	**Indicative Cumulative Noise Attenuation[3]**			**Indicative Cumulative $ Cost (2006)[4] Includes GST**
		63Hz	**dB(A)**	**dB(C)**	
#303 McWhirters - Treat Lounge (bed 1 also benefits)					
Existing - Single level 3 bedroom apartment, enclosed verandah forms soundlock to lounge/bedroom 1, light double glazed windows in external brick wall, sliding glass doors and partition wall between verandah and lounge/ bedroom 1.					
Option 1	Heavy[5] double glazing	5	5	5	18,800
Option 1 + 2	Heavy glazing to sliding door[5], upgrade wall[6]	7	7	7	31,050
Option 1+ 2+ 3	Low Frequency Absorption[7]	10	9	10	49,050
Total	Incl. Preliminary + Craneage Costs				55,600
#305 McWhirters - Treat Lounge (bed 1 also benefits)					
Existing - Single level 3 bedroom apartment, top floor, enclosed verandah forms soundlock to lounge/bedroom 1, light double glazed windows in external brick wall, sliding glass doors and partition wall between verandah and lounge/ bedroom 1.					
Option 1	Roof/ ceiling and skylight[8]	9	10	10	26,700
Option 1 + 2	Heavy[5] double glazing	11	11	12	44,600

Apartment[1] & Option#	Description of Acoustic Treatment[2]	Indicative Cumulative Noise Attenuation[3]			Indicative Cumulative $ Cost (2006)[4] Includes GST
		63Hz	dB(A)	dB(C)	
Option 1+ 2+ 3	Low Frequency Absorption[7]	13	13	14	55,600
Total	Incl. Preliminary + Craneage Costs				62,150
#317 McWhirters - Treat Lounge					
Existing - Single level 1 bedroom apartment, enclosed verandah forms soundlock to lounge/bedroom 1, light double glazed windows in external brick wall, sliding glass doors and partition wall between verandah and lounge/ bedroom 1.					
Option 1	Heavy[5] glazing to inner pane double glazing	3	3	4	11,250
Option 1 + 2	Heavy[5] glazing to sliding door, upgrade wall[6]	4	5	5	19,400
Option 1+ 2+ 3	Low Frequency Absorption[7]	7	6	8	27,450
Total	Incl. Preliminary + Craneage Costs				34,000
#602 McWhirters - Treat Lounge (bed 1 also benefits)					
Existing - Double level 2 bedroom apartment, top floor, bed 1 on upper level and open plan to lounge room on lower level, light sliding glass doors and partition wall to external façade, open verandah.					
Option 1	Roof/ ceiling and skylights[8]	7	5	6	12,600
Option 1 + 2	Heavy[5] glazing to sliding door, upgrade wall[6]	12	11	12	23,100
Option 1+ 2+ 3	Heavy[5] double glaze[9] sliding door	15	15	14	45,500
Option 1+ 2+ 3+ 4	Low Frequency Absorption[7]	16	17	16	57,250
Total	Incl. Preliminary + Craneage Costs				63,800
#20 Fortitude Village - Treat Lounge (bed 1 also benefits)					
Existing - Single level 1 bedroom, top floor, open plan bedroom to lounge room, light sliding glass doors to open verandah, light double glazed window to bedroom, brick external walls.					
Option 1	Roof/ ceiling[8]	2	2	2	9,850
Option 1 + 2	Heavy[5] glazing to sliding door, upgrade wall[6]	7	7	6	18,750
Option 1+ 2+ 3	Heavy[5] glazing to enclose verandah, and to inner pane bed 1 double glazing	11	13	11	38,650
Option 1+ 2+ 3+ 4	Low Frequency Absorption[7]	13	15	13	46,150
Total	Incl. Preliminary + Craneage Costs				52,700

Apartment[1] & Option#	Description of Acoustic Treatment[2]	Indicative Cumulative Noise Attenuation[3]			Indicative Cumulative $ Cost (2006)[4] Includes GST
		63Hz	dB(A)	dB(C)	
# 110 Sun - Treat Lounge (bed 2 also benefits)					
Existing - Single level 2 bedroom, light hinged glass doors to lounge, light single glazed window to bedroom 2, brick external walls.					
Option 1	Heavy[5] glazing to doors and window	5	6	5	12,250
Option 1 + 2	Heavy[5] double glaze doors and window	13	18	13	29,550
Option 1+ 2+ 3	Low Frequency Absorption[7]	15	20	15	41,300
Total	Include. Preliminary Costs[10]				46,150
# 303 Sun - Treat Bed 1					
Existing - Triple level 2 bedroom apartment, top floor, bed 1 on upper level connected to lounge room on lower level, bedroom 1 light hinged glass doors, light windows, partition wall to external façade, open verandah. Lounge room light double glazing.					
Option 1	Roof/ ceiling[8]	3	2	4	7,250
Option 1 + 2	Heavy[5] glazing to doors, window, upgrade wall[6]	8	8	9	19,150
Option 1+ 2+ 3	Heavy[5] double glaze doors and windows, heavy[5] glazing to ensuite window	12	14	13	36,000
Option 1+ 2+ 3+ 4	Low Frequency Absorption[7]	15	17	16	44,550
Total	Incl. Preliminary + Craneage Costs				51,100
# 312 Sun - Treat Bed 1 (lounge also benefits)					
Existing - Triple level 2 bedroom apartment, top floor, bed 1 on upper level connected to lounge room on lower level, bedroom 1 light hinged glass doors, light windows, partition wall to external façade. Lounge light hinged glass doors, sliding windows.					
Option 1	Roof/ ceiling, skylight in ensuite[8] , solid core ensuite door	3	2	3	7,300
Option 1 + 2	Heavy[5] glazing to doors, window, upgrade wall[6]	10	9	10	19,650
Option 1+ 2+ 3	Heavy[5] double glaze doors and windows	13	14	13	33,750
Option 1+ 2+ 3+ 4	Low Frequency Absorption[7] (lounge)	13	14	13	42,300
Total	Incl. Preliminary + Craneage Costs				48,850

Apartment[1] & Option#	Description of Acoustic Treatment[2]	Indicative Cumulative Noise Attenuation[3]			Indicative Cumulative $ Cost (2006)[4] Includes GST
		63Hz	dB(A)	dB(C)	

1. Apartment layout and constructions are described under the Apartment number. Light glazing refers to 4 – 6mm thick glazing. The existing double glazing cavity ranged from 100 – 160mm deep. External brick walls typically 300mm thick. External lightweight walls typically 4.5mm fibre cement sheet exterior, 10mm plasterboard interior.
2. Treatments are described for each option.
3. The indicative noise attenuation has been modelled for the room noted (eg. Treat Lounge), and for the Options shown. The other room where noted (eg. Bed 1 also benefits) indicates that treatments would also logically be applied to reduce noise levels in this room at the same time. The costs include treatments to both rooms in this case.
4. Indicative Cumulative Costs are taken from the Quantity Surveyors data. Costs were based on 2006 rates and could be projected for future years using relevant construction industry escalation factors.
5. 10mm solid glass (noted as heavy glazing in Table 1) has been costed for the windows and doors, however laminated glass could also be considered for safety or acoustic reasons (gives improved mid to high frequency attenuation). Additional cost for 10.38mm laminated glass is $98 per square metre (plus GST). Acoustic seals installed on hinged doors and siding doors and windows where practical.
6. Add insulation in cavity of wall and a layer of 16mm thick plasterboard to one side.
7. Low Frequency absorption modules - refer to discussion in Section 2.4.
8. Add insulation and 16mm plasterboard to ceiling, install 10mm glass under any existing skylights to form double glazing.
9. A second set of doors or windows added inside existing to create double glazing with 200-300mm cavity.
10. No craneage costs expected for apartment #110 Sun.

From Table 1 it can be seen that the attenuation achieved at the 63Hz octave band centre frequency, the overall dB(A) and dB(C) values are very similar. This is due to the low frequency nature of the music noise levels within the apartments, which means that unless the treatments attenuate the low frequency (ie. 63Hz), the overall levels (ie. dB(A) and dB(C)) will not be reduced. Hence all three descriptors tend to show a similar increase in attenuation for each treatment. Where there is less reduction in the 63Hz and dB(C) values than the dB(A) value, this indicates that there was some mid- frequency noise still present inside the room (ie. #110 Sun).

Original walls to the buildings were often solid masonry and provided good attenuation of the low frequency noise, and similarly glazing systems were able to be designed to address low frequency noise reasonably well. One of the more effective approaches was to use the enclosed verandah as a soundlock, providing a large cavity (approximately 2m) between the outer wall glazing and the inner glazing to the lounge or bedroom areas. The limiting elements for attenuation of noise entering roof-top apartments tended to be the roof/ ceiling, and also the lightweight wall constructions. To achieve further improvement in roof/ ceiling performance would require adding more mass, or resiliently mounting or suspending a new heavy ceiling under the existing ceiling. These options were not included in the study as they were considered impractical in terms of cost, weight and ceiling height restrictions.

Double glazing provides moderate attenuation at low frequencies and higher levels of attenuation at mid to high frequencies. This tends to accentuate the low frequency noise experienced within the apartment. Single glazing provides a more even attenuation across the frequency range. The use of single heavy glass (eg. 20mm thick) rather than double glazing could be investigated as it may improve the tonal balance in the room, as well as reducing the overall levels (ie. audio balance). The installation of single heavy glazing may require only the internal glazing to be replaced, which may avoid the need for road closures, and reduce installation costs.

4. CONCLUSIONS

A methodology was developed to provide Brisbane City Council with indicative costs for the treatment of eight existing apartments in Fortitude Valley. During inspection of the apartments it was found that original walls to the heritage buildings were solid masonry and would provide good attenuation of the low frequency noise, and similarly glazing systems were able to be designed to address low frequency noise reasonably well particularly where the veranhah was enclosed to act as a soundlock. The limiting elements for attenuation of noise entering roof-top apartments tended to be the roof/ ceiling, and also the lightweight wall constructions.

The study found that attenuation of 2 – 16dB(C) could be achieved using a variety of site specific treatments with indicative total costs ranging from $34,000 to $64,000. The higher costs tend to relate to apartments requiring roof/ ceiling treatments or with larger rooms (eg. larger window areas to treat). The cost benefit of the treatments based on the 63Hz parameter varies from $3,100 per dB (#110 Sun) to $5,600 per dB (#303 McWhirters). Apartment #110 Sun is smaller than #303 McWhirters, however the data does not appear to show a direct relationship between size of apartment and $ per dB. The $ per dB figure depends on several factors including: area of façade elements to be treated, the level of attenuation that can be achieved for wall and roof constructions, and weather other rooms need to be treated to control flanking noise (eg. internal stairs to another room may require the other room to also be treated). Ultimately the perceived value of the acoustic treatment is expected to depend largely on the owners' attitude towards the noise issues.

Further development work could include: acoustic testing of existing and proposed apartment glazing, consideration of single heavy glazing (eg. 20mm thick) to provide better sound balance within the apartments, and use of masking noise systems to "hide" music entering the apartments.

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