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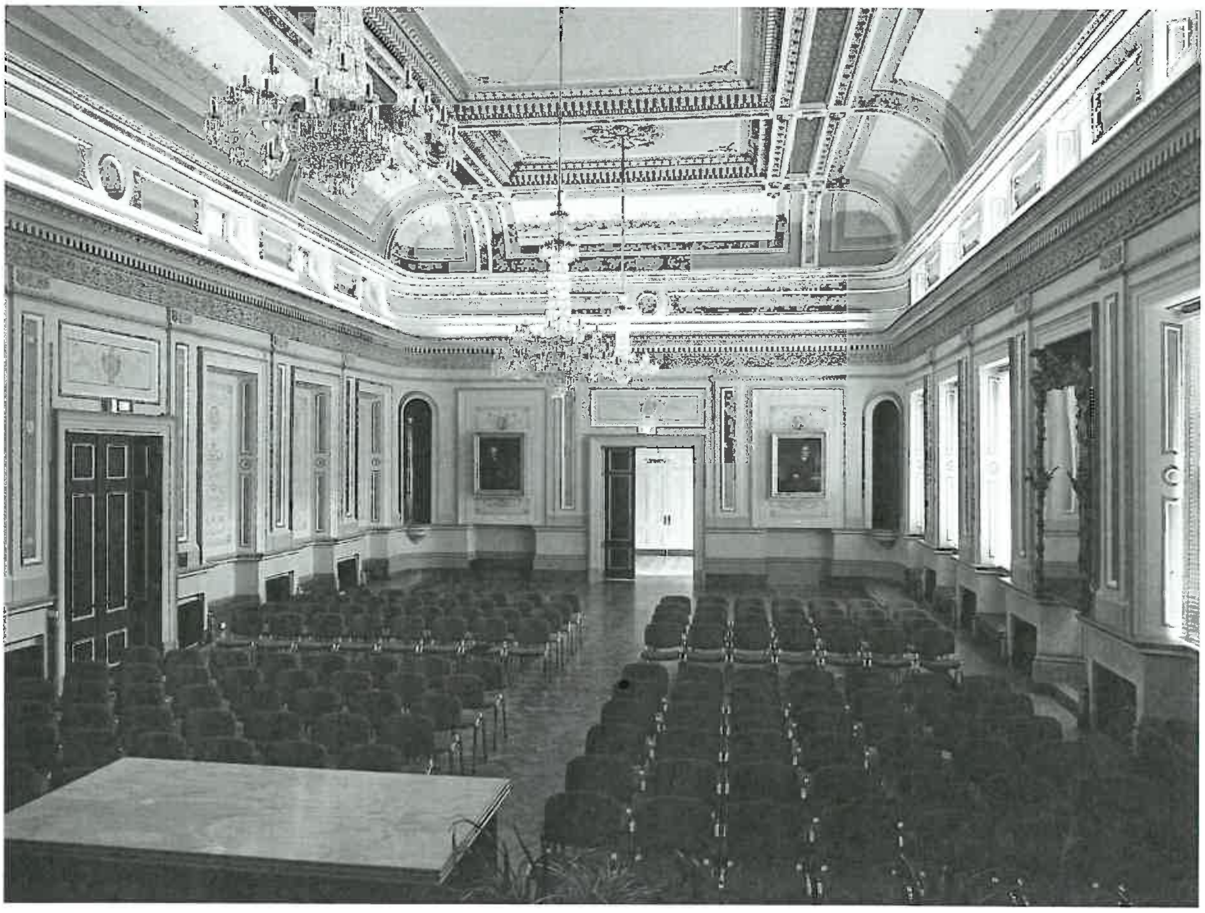
Hobart City Council

Town Hall Ballroom

Acoustic Assessment



Report No. 5124

May, 2016

NVC

NOISE VIBRATION CONSULTING

EXECUTIVE SUMMARY

The Hobart City Council has requested that a report be prepared documenting the quality of the acoustics of the Hobart Town Hall Ballroom, and remedial actions that may be taken to improve the levels of instrumental and speech intelligibility.

NVC has conducted that assessment by initially measuring the current room acoustic conditions and comparing them against various acoustic performance indices. The main indices of the reverberation time (RT60), and Speech Transmission Index (STI), were measured as 2.8 seconds and 0.51 respectively. These imply the space has excessive reverberation for both music and speech, with the result that speech in particular will be difficult to understand. Background noise levels from traffic on Macquarie street were found to be a secondary effect.

To improve the rom acoustics a reduction in the reverberation time was then the primary design aim. To understand how this might be achieved, an acoustic model of the space was developed using the CATT-Acoustic platform. Having validated the model against the measured performance, the model was used to investigate the placement and type of sound absorber to use in the hall, with the following recommendations emerging:

- Install 100mm Autex Quietspace panels or similar in the Eastern alcoves and in the lower section of all alcoves.
- Install heavy weight, high drape curtains to the upper level of the eastern and western walls.
- For classical music have the curtains retracted, and for speech or amplified music have them fully drawn.

Applying acoustic treatment to the main window blinds was found to be ineffective, and any changes to those blinds then at the architect's discretion.

Further effort to improve the room acoustics then looked at reducing traffic noise ingress from Macquarie street, and ensuring the public address (PA) system was configured appropriately for the room and its intended use. The following additional recommendations resulted from this:

- Tune the PA system for two settings, music and speech. These "tuned" settings are stored as pre-sets for recall at any time.
- When using the PA system, the performer should be on stage and not on the longer side wall.
- The sash windows be sealed around their perimeter and their glazing upgraded to 10mm laminate.
- Install a heavier door set and full frame for access to the balcony and install effective acoustic seals and latching mechanisms.

DOCUMENT CONTROL

TOWN HALL BALLROOM
ACOUSTIC ASSESSMENT

Job No:
1133

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INTRODUCTION

The Hobart town hall ballroom is used by the Hobart City Council for a wide variety of uses (music recitals, speech, drama, social gatherings etc.), and the Mayor has asked for the acoustics of the space to be reviewed. The review was prompted primarily by feedback from users of the space noting difficulty with speech intelligibility throughout the space and some musicians finding it too "loud". That review has been conducted by NVC over the months of January to April 2016 and is reported on in this document.

The review focused on establishing the current acoustic conditions of the space and then building an acoustic model of the space using the CATT-Acoustic software. That model enabled understanding of how the space worked acoustically and then allowed for simulations of various remedial options to be assessed. The options that were considered most feasible were then costed to provide a budget estimate for remedial works.

1.0 THE TOWN HALL BALLROOM

The ballroom is on the first floor of the town hall with its western wall being the facade to Macquarie street and its remaining walls being internal. The general dimensions of the space are 25 m long, by 14 m wide, by 8 m high giving a main room volume of some 2,300 m^3.

Figure 1: Ballroom Looking North to the Stage

Its general construction is masonry with plaster rendering and includes extensive ornamental plasterwork (cornices, ceiling roses etc.). The Macquarie street facade has a set of 6 window alcoves which have sash windows with a secondary glazing panel in front of them. Venetian blinds are used in front of the windows. The window alcoves are duplicated on the opposite eastern wall where they are solid masonry fill instead of glazing. The floor is polished timber parquetry.

A raised stage is at the northern end of the ballroom, the stage being timber framed with Tasmanian oak flooring. A large volume off the back of the stage houses the organ pipes.

A public address (PA) system is permanently installed with speakers mounted on the side walls just in front of the stage at a height of 3.5m. The sound system controls are located in a small room across the corridor from the ballroom. The PA is typically used for all events where speech is required, and the particular group using the ballroom control the sound system set up.

When seating is required, steel frame, padded seats are used, a full hall holding some 200 seats and a typical set up some 140 seats.

Figure 1 and Figure 2 show the inside of the ballroom from the rear of the room and the stage respectively.

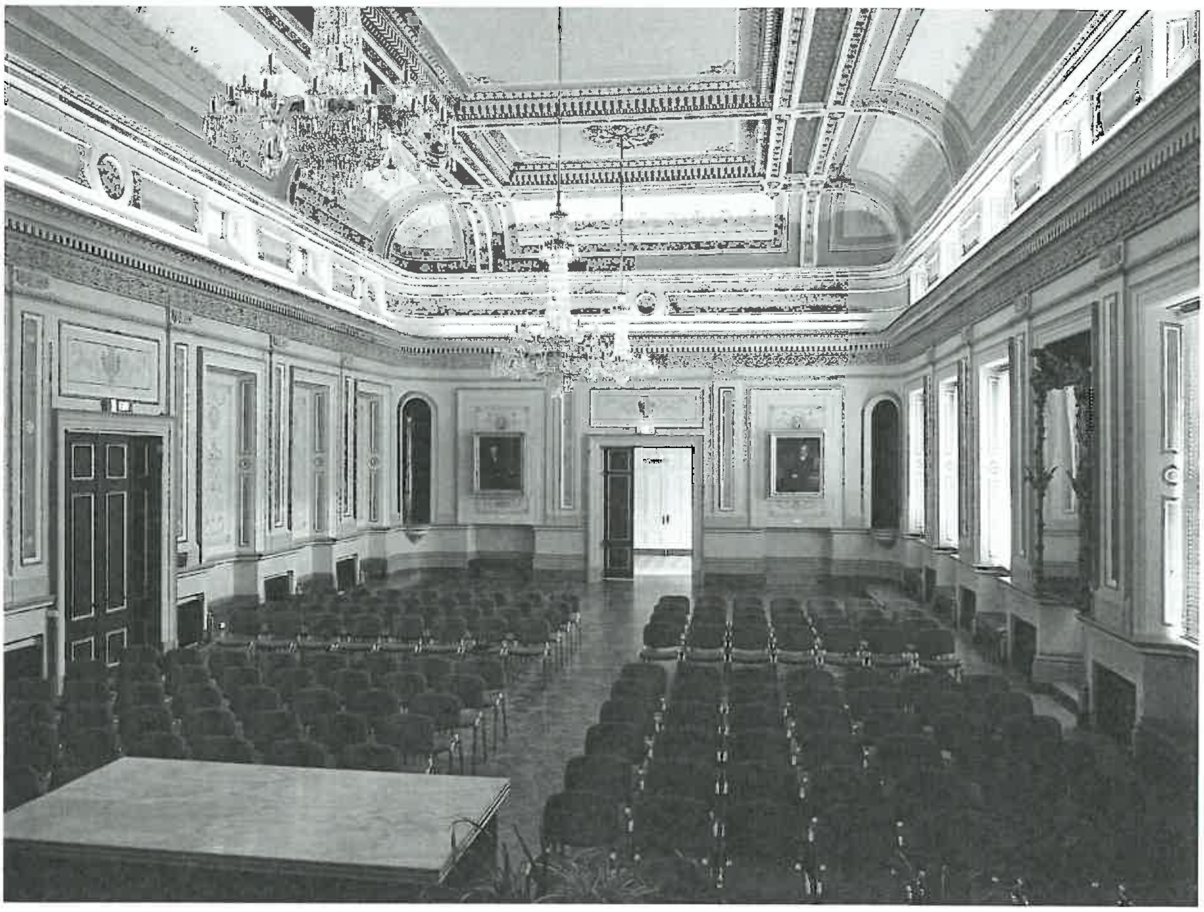

Figure 2: Ballroom Looking South from the Stage

2.0 ROOM ACOUSTIC MEASURES

The predominant description of a room's acoustical quality is the reverberation time; the time taken for a sound to decay by 60 decibels. If the reverberation time is too high then one sound "runs into" the next sound and distorts our perception of the sound. Music requires some reverberation to develop what we perceive as envelopment by the music, while speech requires minimal reverberation so that each sound is clearly separated and intelligible. Thus spaces cannot achieve good performance for both music and speech – a choice must be made as to the dominant use of a space and then that use dictates the design.

Background noise clearly impacts the acoustics of a space by masking the sound that is to be heard (speech or music), and reducing the background to a minimum is clearly desirable.

Beyond these simple measures there are more subtle design aspects that look at room geometry and the provision of appropriate early reflections off wall or ceiling surfaces.

For speech a measure that combines the effects of reverberation and background noise is the Speech Transmission Index (STI) for unaided speech, and the STI PA for speech aided by a PA system.

For the review of the Town Hall ballroom, the reverberation time, the background noise, and the STIPA were used as the predominant design parameters.

In designing a space for a particular use the volume and general shape are first determined. The general shape of the town hall is good (rectangle so allows good reflections), but its volume to seating capacity is very high; ideally the volume would be significantly less. The reduced volume would be via a lower ceiling and / or raked seating. It is this high room volume that is broadly speaking the initial cause of the poor room acoustics.

2.1 REVERBERATION TIME CRITERIA

Different uses require significantly different reverberation times to provide an optimum auditory experience. **Table 1** shows typical reverberation times for a range of uses. It is noted that speech requires a time around 1 second while music or choral performances require a time around 1.5 to 2 seconds. From the description of the Ballroom use conveyed by Council, a reverberation time of 1.2 seconds has been determined as the design target. It is noted this is a compromise between good speech and music conditions with a leaning to good speech conditions.

INTENDED USE	RT60 REVERBERATION TIME RANGE
Speech only	< 1.0s
Amplified music	< 1.0s
Classical music	1.6 – 2.2s
Opera/chamber music	1.3 – 1.8s
Choir	1.6 – 2.0s
Organ	>2.5s

Table 1: Typical Reverberation Times

The reverberation time varies as a function of frequency, typically being longer at low frequency and then reducing at high frequencies. For music a longer low frequency (bass), reverberation time is considered good as it provides a consistent perceived frequency balance throughout the range. For speech or amplified music a flat reverberation time is desirable. The bass ratio describes this variation with frequency, with a value of 1.12 recommended for music and 1.0 for speech.

2.2 STIPA CRITERIA

The measurement of the STIPA is defined in the International Standard IEC 60268-16 and the Standard provides a qualification scale as shown in **Table 2**, for the interpretation of the STIPA value.

From the Table, a design rating of E or D for the STIPA is determined for the Town Hall Ballroom.

RATING	STIPA RANGE	EXAMPLES OF TYPICAL USES
A+	> 0.76	Recording studios
A	0.72 – 0.76	Theatres, speech auditoria, parliaments, courts
B	0.68 – 0.72	Theatres, speech auditoria, parliaments, courts
C	0.64 – 0.68	Teleconference, theatres
D	0.60 – 0.64	Class rooms, concert halls
E	0.56 – 0.60	Concert halls, modern churches
F	0.52 – 0.56	PA in shopping malls, public offices, cathedrals
G	0.48 – 0.52	PA in shopping malls, public offices
H	0.44 – 0.48	PA in difficult acoustic environments
I	0.40 – 0.44	PA in very difficult spaces
J	0.36 – 0.40	Not suitable for PA systems
U	< 0.36	Not suitable for PA systems

Table 2: STIPA qualification scale

3.0 EXISTING ACOUSTIC PERFORMANCE

The current acoustic quality of the ballroom has been measured under the following conditions:

- Unoccupied.
- All seats stacked together, at the side of the room.
- Doors and windows shut.
- During the morning with the dominant background noise source as traffic on Macquarie street.

The reverberation time was measured using a starter pistol to create an instantaneous impulse and logging the sound decay with a SVAN 977 sound level meter. The sound decay curves were valid for the one third octave bands from 80 Hz to 8 kHz, with the spatially averaged reverberation time spectrum being shown in Figure 3. From the spectrum, the mid frequency reverberation time is determined as 2.8 seconds. It is noted the spectrum shows an unusual drop in reverberation times at the low frequencies and this is attributed to the organ pipe space behind the stage.

The STIPA was measured using an NTI acoustic analyser. A STIPA test signal was connected to the microphone input channel of the PA system and the amplifier gain adjusted to give a test signal noise level within the ballroom of 73 dBA. The STIPA was then measured at various locations throughout the room, being repeated several times at each location to ensure accuracy of the measurement. The STIPA results ranged from 0.46 to 0.55 with an average of 0.505. This gives a rating of G implying a level of speech intelligibility that may be expected in a shopping mall or public office.

The external noise level to the Macquarie Street facade was measured over a period of several hours and showed a cyclic nature (traffic flow dictated by lights), varying between typically 55 and 65 dBA. Single louder pass by events are observed up to 80 dBA.

The background noise was measured centrally within the room and found to be an Leq 45 dBA (i.e. average) or NR40. Instantaneous noise levels varied between 40 and 60 dBA with the latter being due to a truck passing by using engine brakes.

The existing ballroom performance is then summarised in Table 3. The following comments are relevant with regard to the Table:

- The measured STIPA reflects comment from Council that speech is difficult to understand.

- The background noise level is not causing poor intelligibility when the PA is used as it is well below the levels the PA will produce.
- Unamplified speech will be adversely effected by the background noise level, as will any musical performance.
- The high reverberation time (suitable only for organ recital) is then the most significant factor in reducing the STIPA rating and causing the poor intelligibility. The reverberation time is also too high for most genres of music.

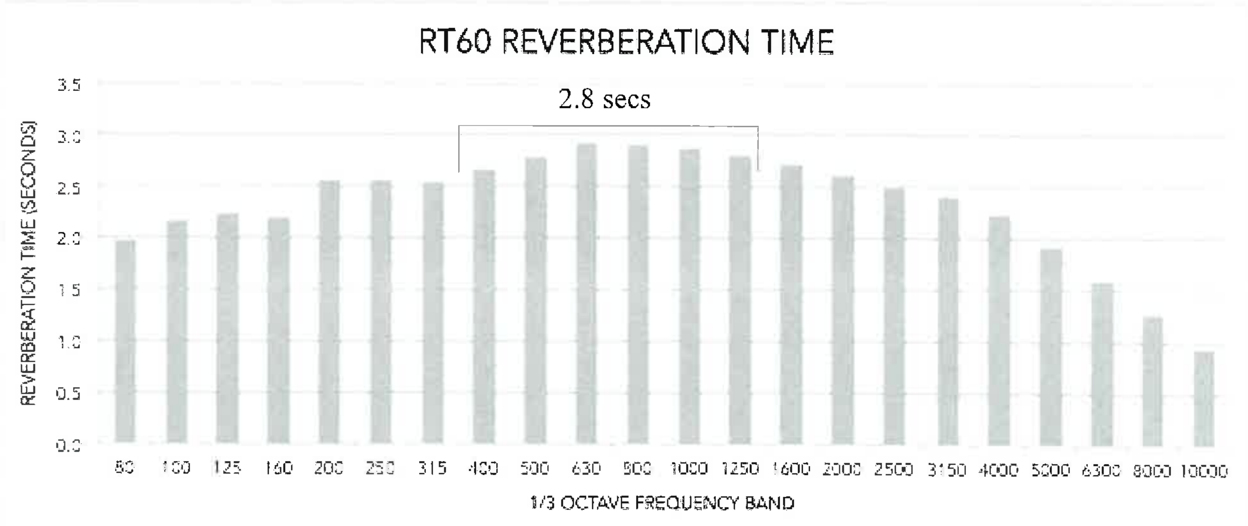

Figure 3: Current One Third Octave Reverberation Time

	Measured	Criteria
Reverberation time (seconds)	2.8	1.2
Bass Ratio	0.8	1
STIPA	0.505 G	≥ 0.56 (E)
Background Noise Leq dBA	43	35 - 40
External Noise Leq dBA	64	N/A

Table 3: Current Acoustic Performance of Ballroom

4.0 ROOM MODIFICATIONS

4.1 REVERBERATION TIME

As it is currently configured, the ballroom is most critically in need of treatment to reduce the reverberation time with a design target of 1.2 seconds that shows a relatively flat response. Observing the current reverberation time curve in Figure 3 it is evident this implies remedial action that is most effective in the mid frequency range (500 to 2000 Hz), but also provides low frequency performance.

Reverberation is caused by multiple reflections of the sound that are reflected with little loss of energy. Given the room geometry is fixed, the only way to reduce reverberation is to provide surfaces for reflection that offer considerable loss of energy to the reflected sound. This implies placing additional surface treatments to the ballroom that are "soft" and afford high sound absorption. Such surface treatments may be either porous or panel types with the panel being effective over only a narrow range in the low frequency region, and the porous absorber effective over a much wider frequency range while still effective at lower frequencies provided it is thick enough. The porous absorber is then the most effective solution, due to its performance across all frequencies.

Several types of porous absorber have been investigated for this work viz:

- Autex Quietspace panel. Available in a wide range of colours and thickness. May have screen printed facing.
- Barrisol micro-perforated screen. Very thin, may be screen printed or translucent, housed within a frame that must be 100 to 300 mm off the surface behind it.
- Curtains. Heavy material with significant drape to be effective. May be retracted or drawn so offer a variable acoustic effect.
- Window Blinds. Are required anyway so acoustic benefit a potential plus. Roman Blinds or venetian type. Romans will be heavy and exclude all light.

The sound absorption afforded by these products are indicated in Table 4 where a value of 0 is no absorption and 1 is full absorption.

MATERIAL		OCTAVE BAND ABSORPTION COEFFICIENT, α					
		125	250	500	1000	2000	4000
Base Building							
Window	Macquarie St windows and high level windows	0.20	0.10	0.08	0.06	0.04	0.02
Painted Plasterwork	Walls and ceiling	0.04	0.03	0.04	0.05	0.05	0.02
Polished Parquetry Floor	Floor	0.15	0.12	0.10	0.07	0.06	0.07
Stage	Stage floor	0.40	0.30	0.20	0.17	0.15	0.10
Organ Pipe Space	Back wall of stage	0.40	0.40	0.40	0.40	0.40	0.40
Remedial Treatments							
Autex Quietspace 100mm	East wall alcoves	0.91	0.99	0.99	0.99	0.98	0.99
75 mm		0.56	0.99	0.99	0.99	0.98	0.99
Barrisol Micro-perforated Screen	East wall alcoves	0.20	0.15	0.65	0.80	0.55	0.55
Curtains, 650 gsm, 50% drape	East / west walls from ceiling to top of main alcove	0.14	0.35	0.55	0.77	0.70	0.60
Window Blinds Roman		0.10	0.50	0.95	0.95	0.99	0.99

Table 4: Sound absorption coefficients for various products.

4.2 PA SYSTEM

The PA control system settings may be optimised for the type of room use (music or speech). Once the room modifications have been completed the PA system performance is tuned via measuring the room response spectrum and adjusting the PA system parameters to achieve the desired response shape. By conducting the optimisation for various room uses, the settings for each use may be stored as pre set configurations on the control system that may then be recalled dependant on the room use. Parameters that may be tuned include:

- Frequency response
- Time delay or reverberation
- Sound pressure level.

4.3 BACKGROUND NOISE

The background noise is dominated by traffic noise intrusion from Macquarie street. The noise enters the room via the windows and the doors to the balcony, the latter being the weakest link. To improve the sound isolation offered by this facade, upgrading of the doors and window construction is required. Options considered are:

Doors — Upgrade the doors (heavier), and their frame, so that the doors can be sealed appropriately around their entire perimeter, and the windows above also sealed against the frame.

Windows — Replace current sash window glazing (5mm float), with 10mm laminated. This provides a 5dB improvement in sound isolation for the glazing alone.

Use a silicone sealant to seal all around the outer sash windows (no longer operable therefore).

Improve the sealing of the internal glazing leaf. Currently it is in two halves and they are not reliably or consistently sealed against the frame.

Upgrade the internal glazing with 10mm laminated. Installed as a fixed pane ideally.

With the door having the worst performance due to significant gaps it should be targeted first, and then the windows assessed.

5.0 ACOUSTIC MODELLING

The development of an acoustic model of the town hall allows accurate evaluation of the range of treatment solutions possible (what materials and where), which in turn gives confidence in achieving the designed performance in practice. The modelling platform used for this work was the CATT-Acoustic software, and its application to the ballroom is described in the following sections.

5.1 ACOUSTIC MODEL

The CATT-Acoustic 3D model has been built based primarily on NVC's measurements / observations of the ballroom geometry and surface finishes. The model is shown in Figure 4, with the surface finishes used listed in Table 4.

The measured versus modelled reverberation time is shown in Figure 5, with further acoustic performance indices listed in Table 5. The good agreement between model and measured is taken as validation of the model.

	MEASURED	MODELED
Reverberation time (seconds)	2.8	2.84
Bass Ratio	0.8	0.85
STIPA	0.505 G	0.44 H
Clarity, C-50		-4.0
Definition, D-50		28%

Table 5: Modelled versus Measured Performance

5.2 MODIFIED ACOUSTIC PERFORMANCE

With the basis for the modifications being to reduce the reverberation time, the choices centred around what absorptive treatment to use and where to locate it. The following options have been considered:

- Absorption on the ceiling. The potential area is large and is to an extent removed from direct view. The attachment of panels directly to the ceiling was considered, Figure 6. The panels would need to be 100mm thick to achieve useful absorption at low frequency and discussion with the installer indicated joints between such panels would be clearly visible and look "messy". He further indicated applying them at the height of the ceiling would be difficult.

  Panels could alternatively be suspended from the ceiling, Figure 6, but this configuration does not have sufficient low frequency absorption (uses only 25mm panels).
- Absorptive panels in the alcoves of the east wall. Two options for the panel were considered, the Autex 100mm panel, or the Barrisol micro-perforated screen.
- Curtains over the Macquarie Street windows. Replace the existing blinds with roman blinds. The area is relatively small (2% of total) so the absorption coefficient would have to be high to have significant impact.
- Acoustic blinds to replace the existing venetian blinds. Again the absorption coefficients would need to be high.
- Curtains in the area between the top wall cornice and the top of the alcoves. The available area is large so there is potential for effective control.

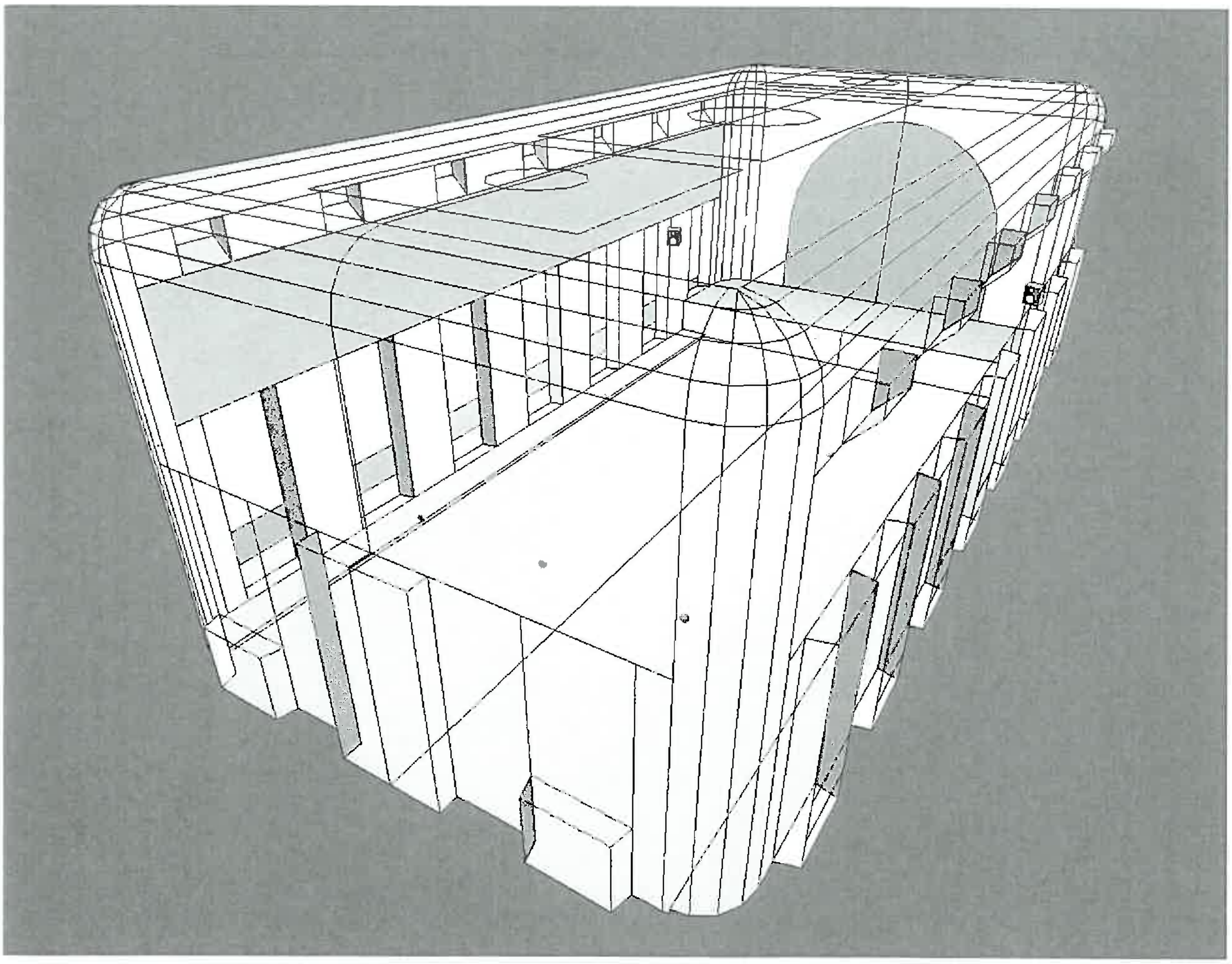

Figure 4: CATT Acoustic Model of the Hobart Town Hall Ballroom

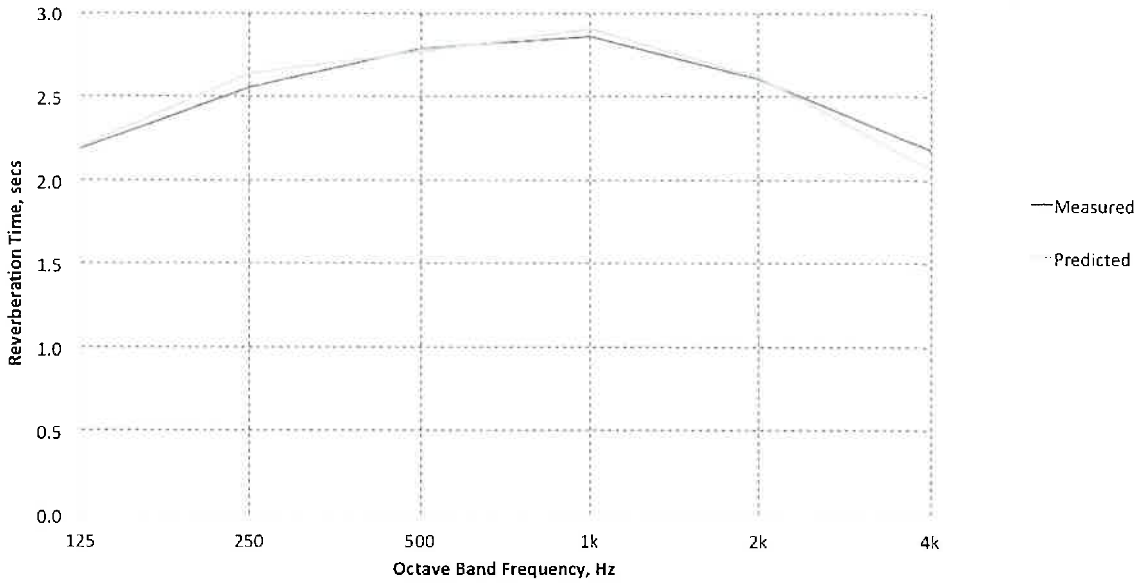

Figure 5: Predicted vs. Measured Reverberation Time

In assessing these options the following needs to be considered:

- It is relatively easy to achieve absorption at high frequency but more difficult to achieve it at low frequency. As such greater areas are often required to achieve appropriate levels of low frequency absorption.
- A significant area of thick panel absorbers such as Autex Quietspace is strongly recommended to provide the low frequency absorption required for a consistent frequency balance. The flat areas of the ceiling are an ideal place for such a product, as it is out of the general view and a large area. The eastern alcoves is another significant, flat area.
- The Barrisol micro-perforated mesh provides good absorption at mid and high frequencies, and provides a subtle covering for the alcoves or other areas of existing artwork which retains visibility. The mesh is mounted within a frame, and this is then mounted as required (similar to a picture).
- Acoustic blinds may provide significant mid and high frequency absorption, along with being a simple and aesthetically pleasing product to install. Blinds provide the additional benefit of operable reverberation control: they may be easily opened to provide an increase in reverberation time for uses which benefit from it.
- Curtains would be a heavy material (>600 gsm) and have at least 50% drape. They then afford good mid to high frequency absorption and "fair" low frequency absorption. As with blinds they provide the additional benefit of operable reverberation control.
- If curtains (traditional or roman) are used on the windows, they will block all light when used. Their use on the main windows on the Macquarie street wall is then not considered practical.

From this discussion the following options have been pursued:

A. Autex 100mm panels in the eastern alcoves and the bottom of all alcoves plus curtains on the upper section of both walls, Figure 7.

B. Autex 100 mm panels on the ceiling and Barrisol screen in the eastern alcoves, Figure 8.

C. Curtains / Blinds on the windows, Figure 9.

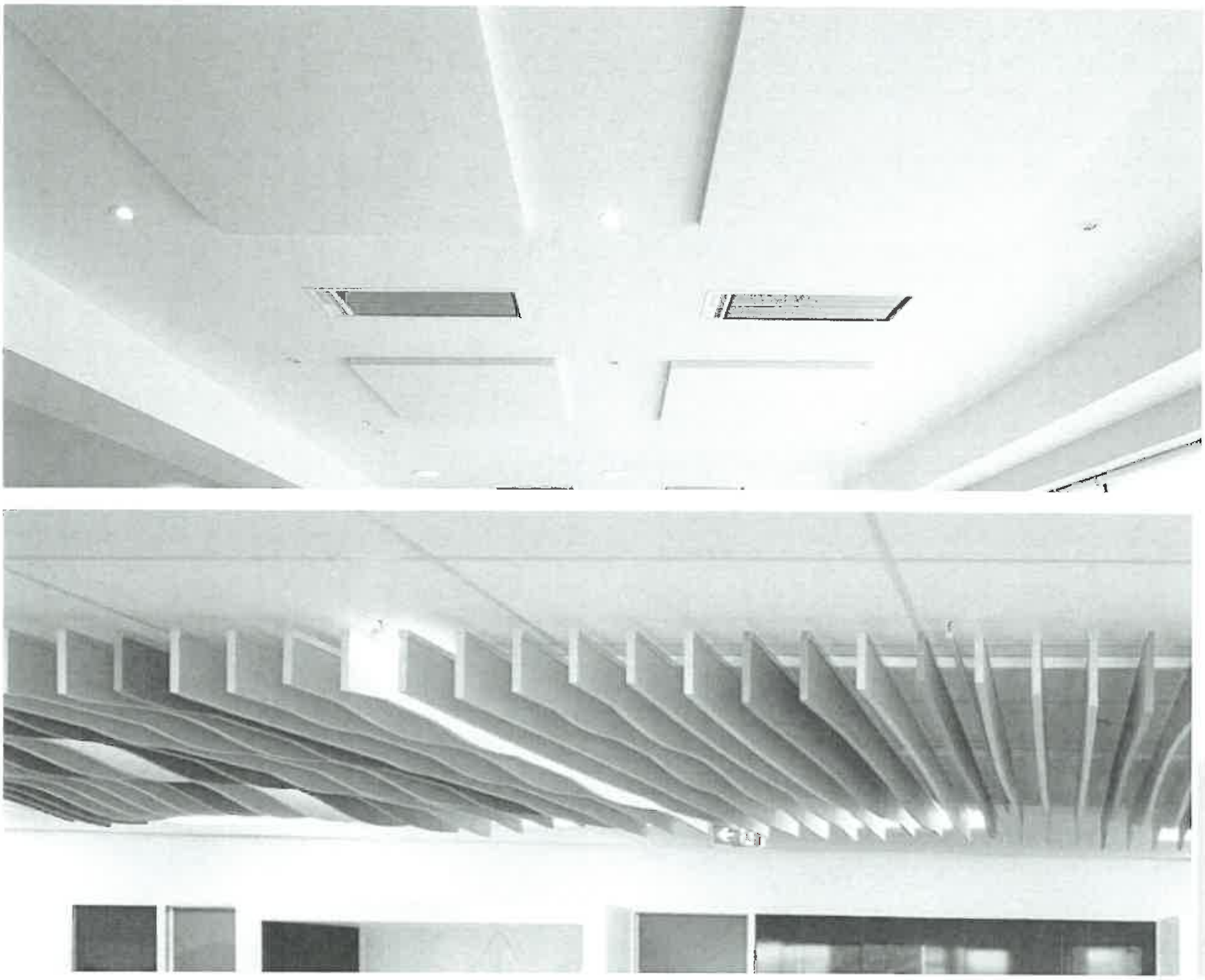

Figure 6: Example of panels attached to the ceiling

The key acoustic performance parameter of reverberation time is shown for each of these options in Figure 10 and Figure 11, and all parameters are summarised in Table 6. Further parameters are compared in Figure 12 to Figure 14. The following is noted:

- The roman blinds on their own (option C) provide only minimal improvement in the reverberation time.
- Option B has the best reverberation curve shape but the reverberation is too high for speech.
- Option A, curtains to the upper wall sections in combination with 100 mm panels to the alcoves, provides the best performance for speech (RT60 low, STI high), and also offers a degree of variability by having curtains that may be retracted. When ½ retracted conditions move toward being acceptable for music and when fully retracted are becoming acceptable for classical or chamber music.
- Option A provides a more even reverberation time across the ballroom than is currently experienced (a variation of some 1.1 secs that reduces to 0.6 secs)
- With absorption applied on one wall (East alcoves), good lateral reflections are limited and this will detract from musical performances.

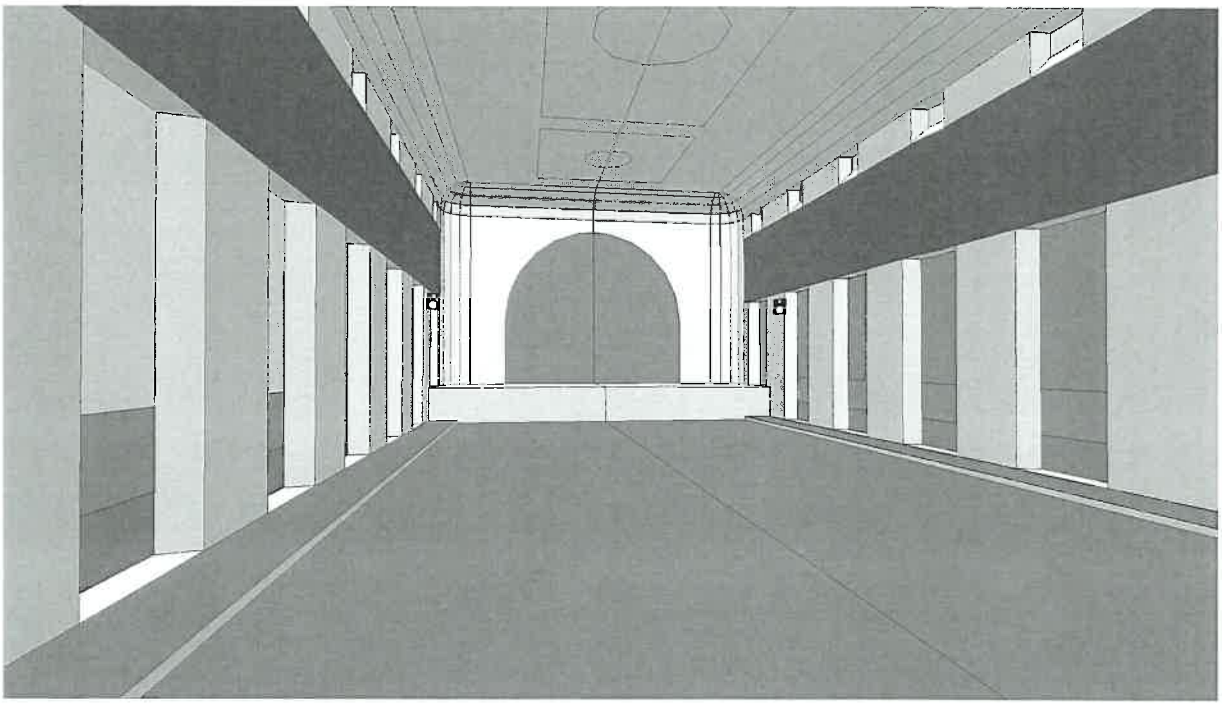

Figure 7: Option A, Curtains on the upper wall and panels in east wall alcoves

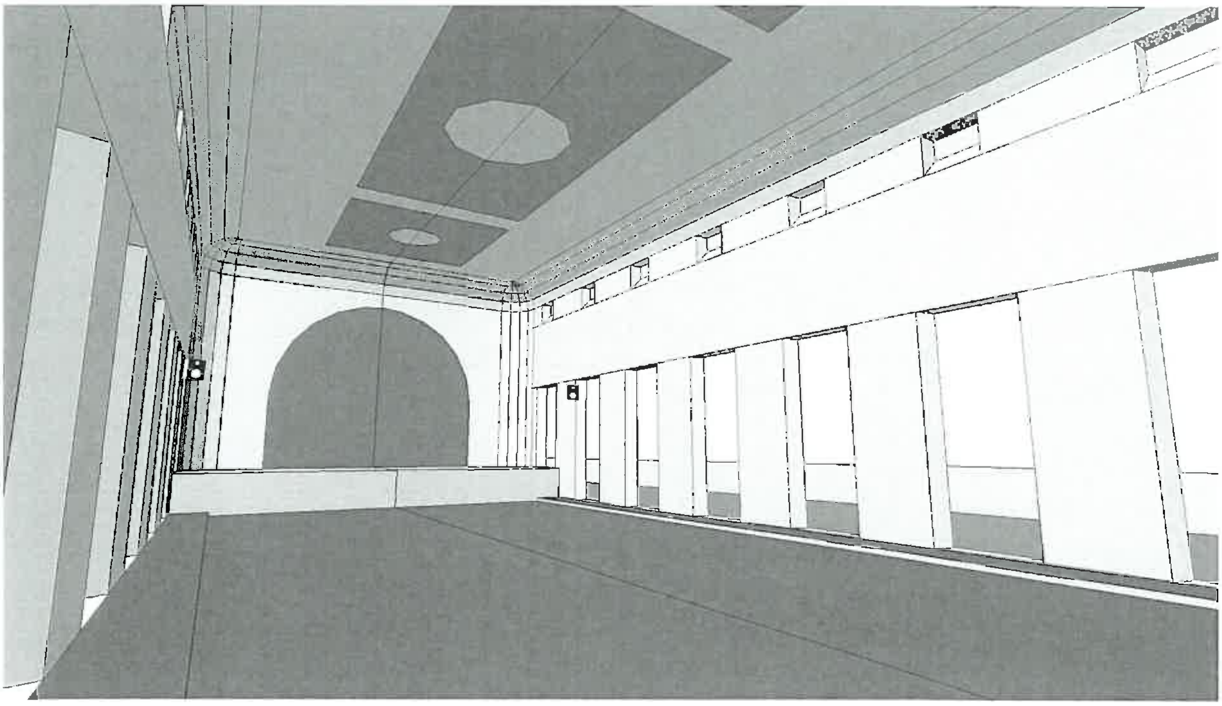

Figure 8: Option B, Ceiling panels and Barrisol screen in east wall alcoves

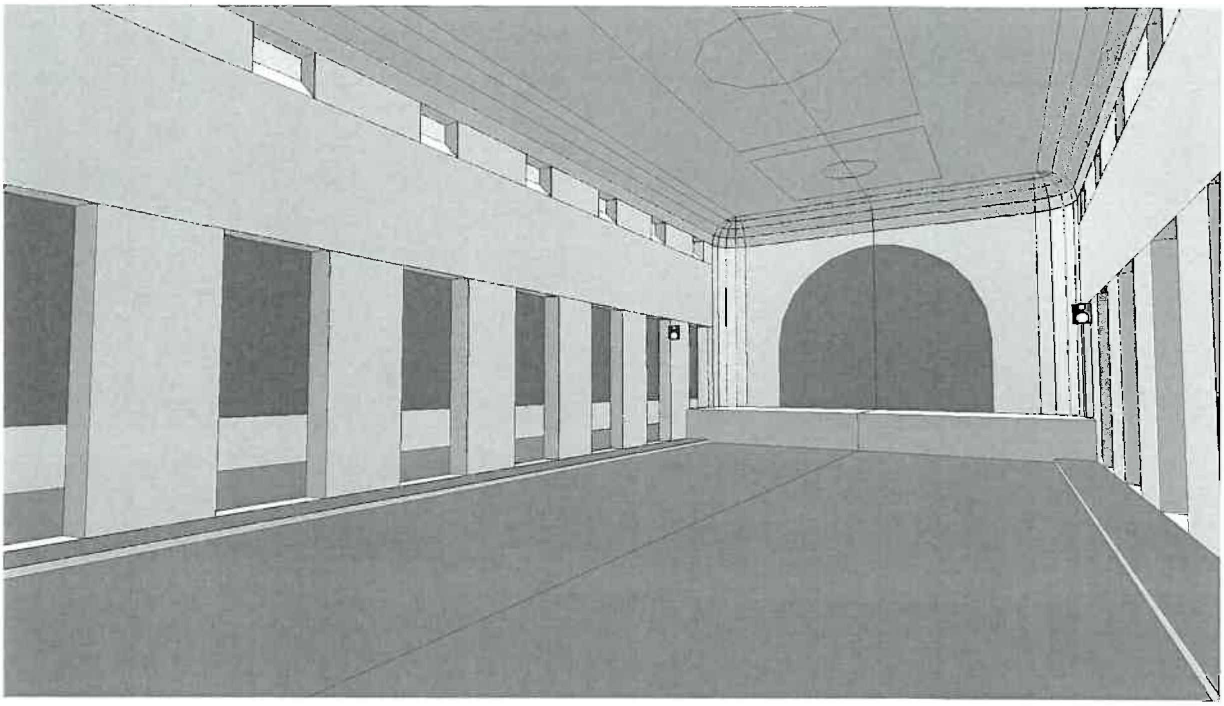

Figure 9: Option C, Window Curtains / Blinds

	Option	RT60 secs	BR	STI	C50 dB	D50 %
		Acoustic Performance Parameter				
A	Curtains in top section of both walls	1.72	1.15	0.51	-1.9	40
	As above + 100mm panels in east alcove and all lower alcoves	1.32	1.17	0.56	-0.5	46
	Curtains on west wall, Panels as above	1.64	1.10	0.52	-1.6	39
	No Curtains, Panels as above	1.98	0.95	0.49	-2.4	36
B	Barrisol in East Alcove, 100mm panels on ceiling	1.52	1.07	0.53	-1.3	40
C	Roman Blinds on Main Windows	2.35	0.97	0.48	-3.2	32
	Target	1.2	1.0	>0.56	-4 to 0	> 60

Table 6: Modified Acoustic Performance

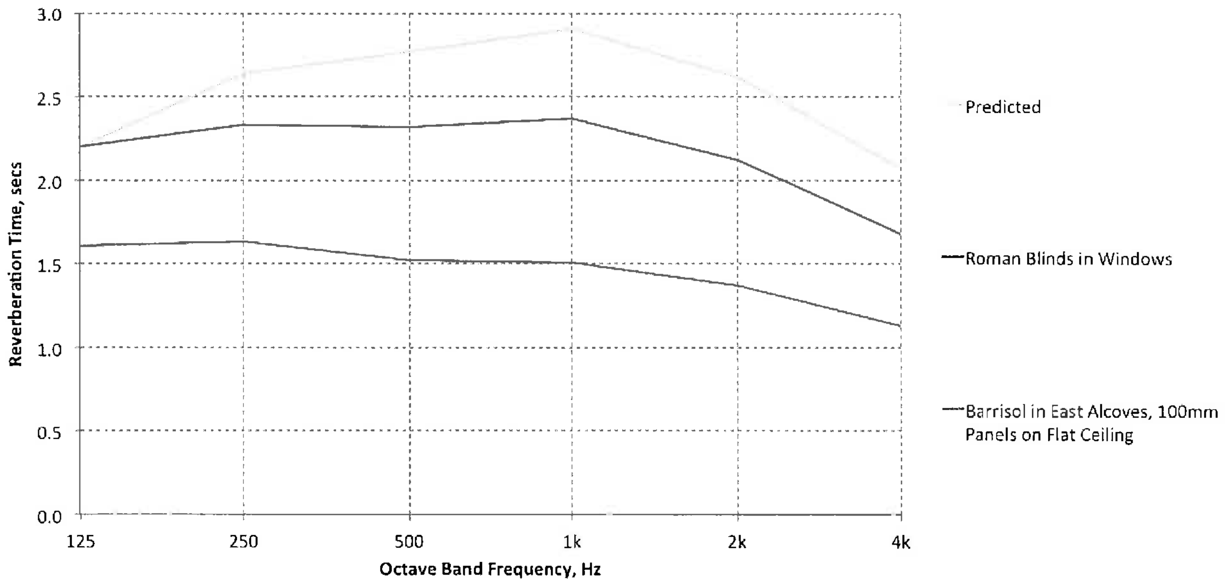

Figure 10: Reverberation Times for Options B and C

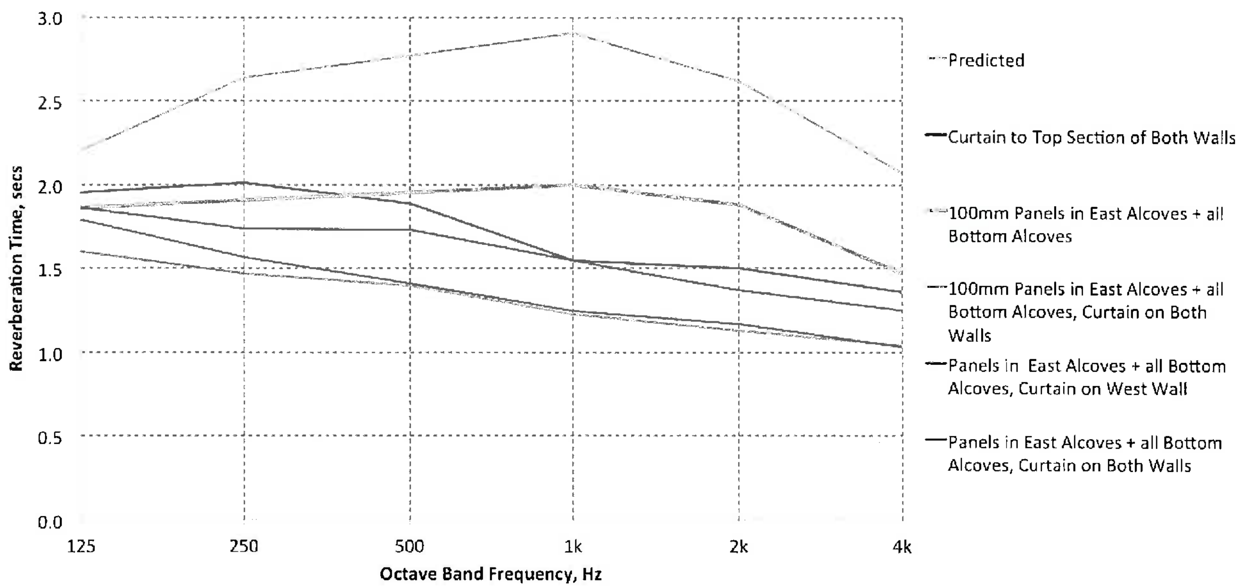

Figure 11: Reverberation Times for Option A

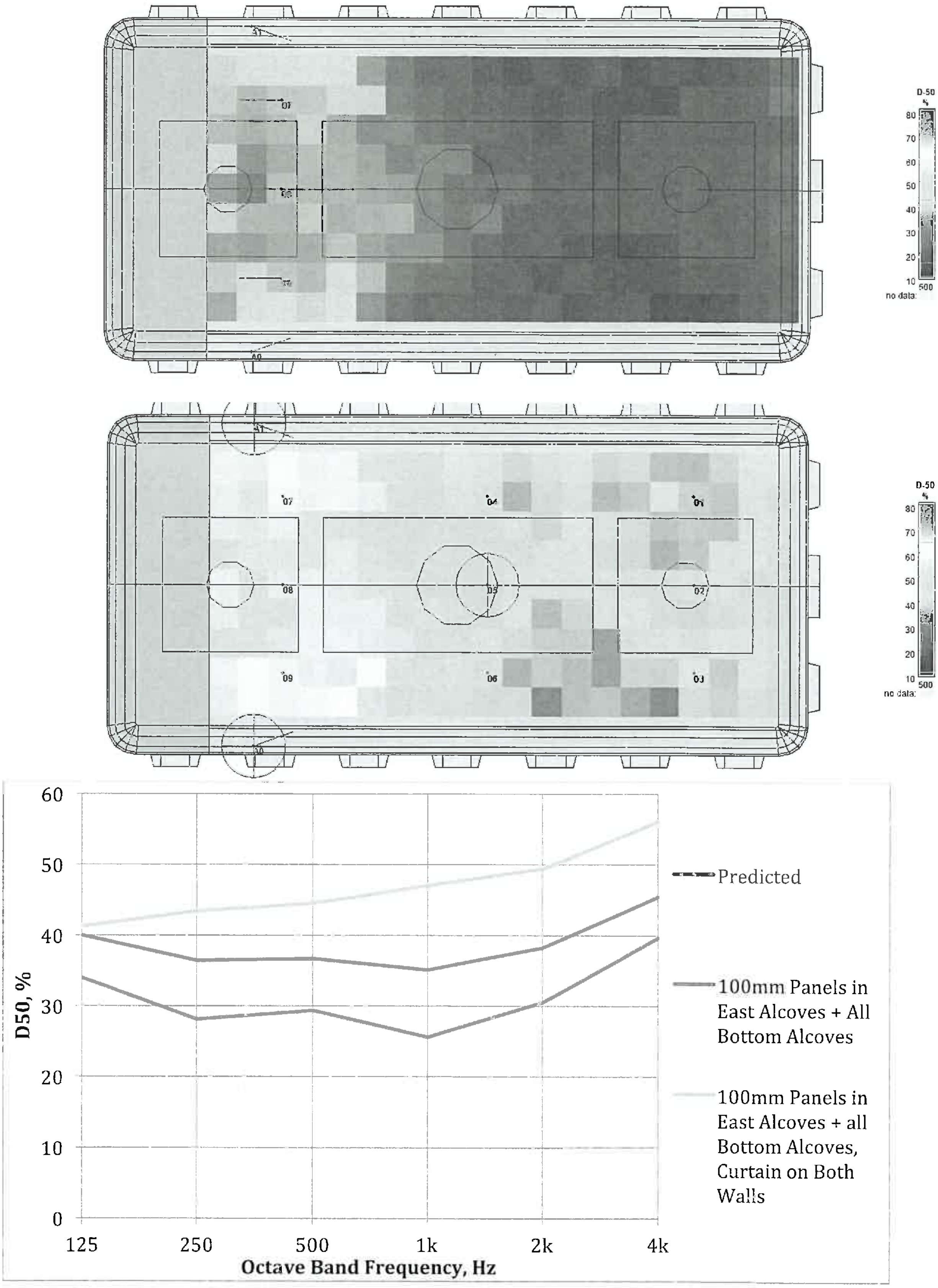

Figure 12: Speech Clarity, D50 – Before and After Treatment (option A)

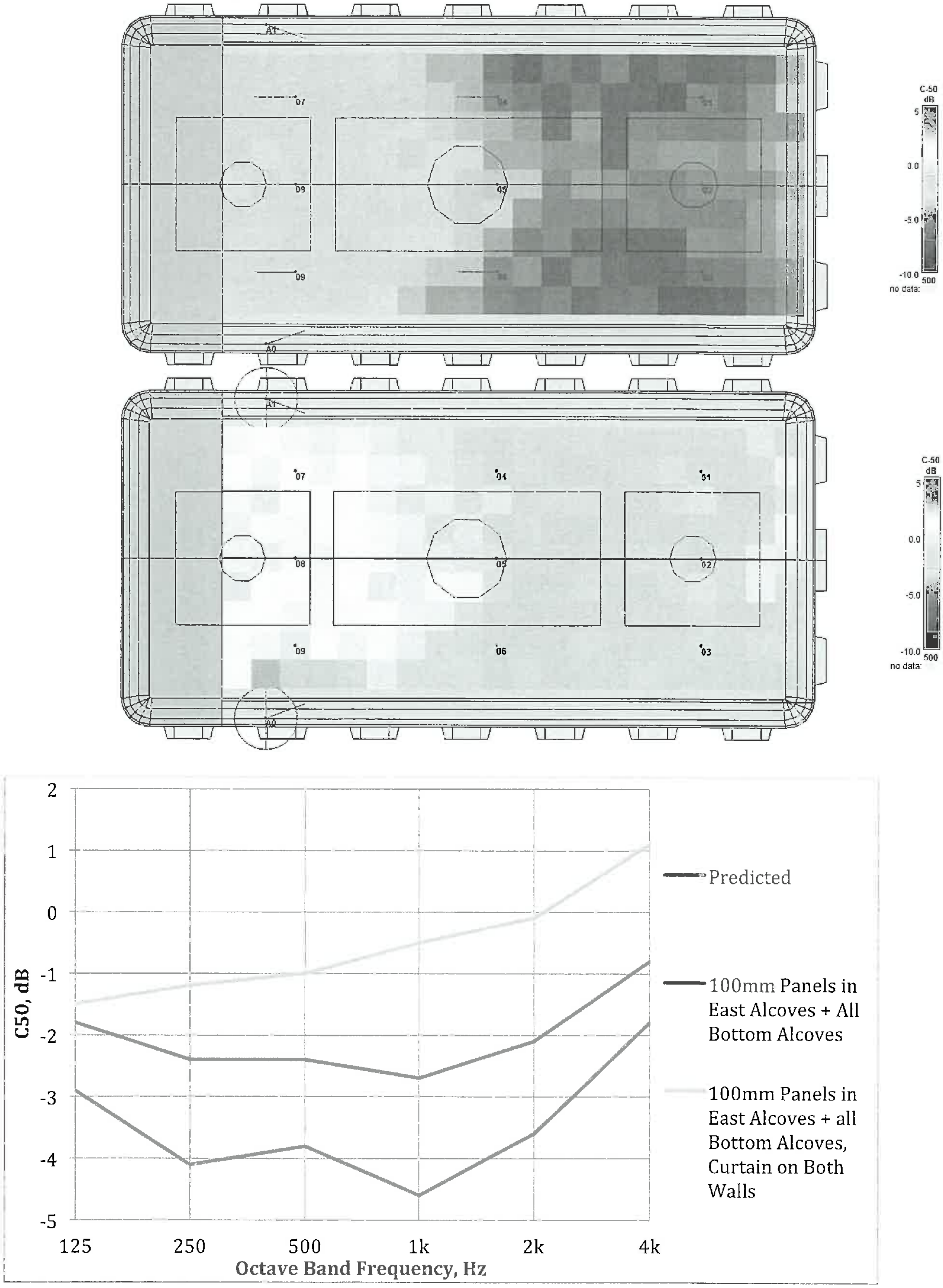

Figure 13: Musical Clarity, C50 – Before and After Treatment (option A)

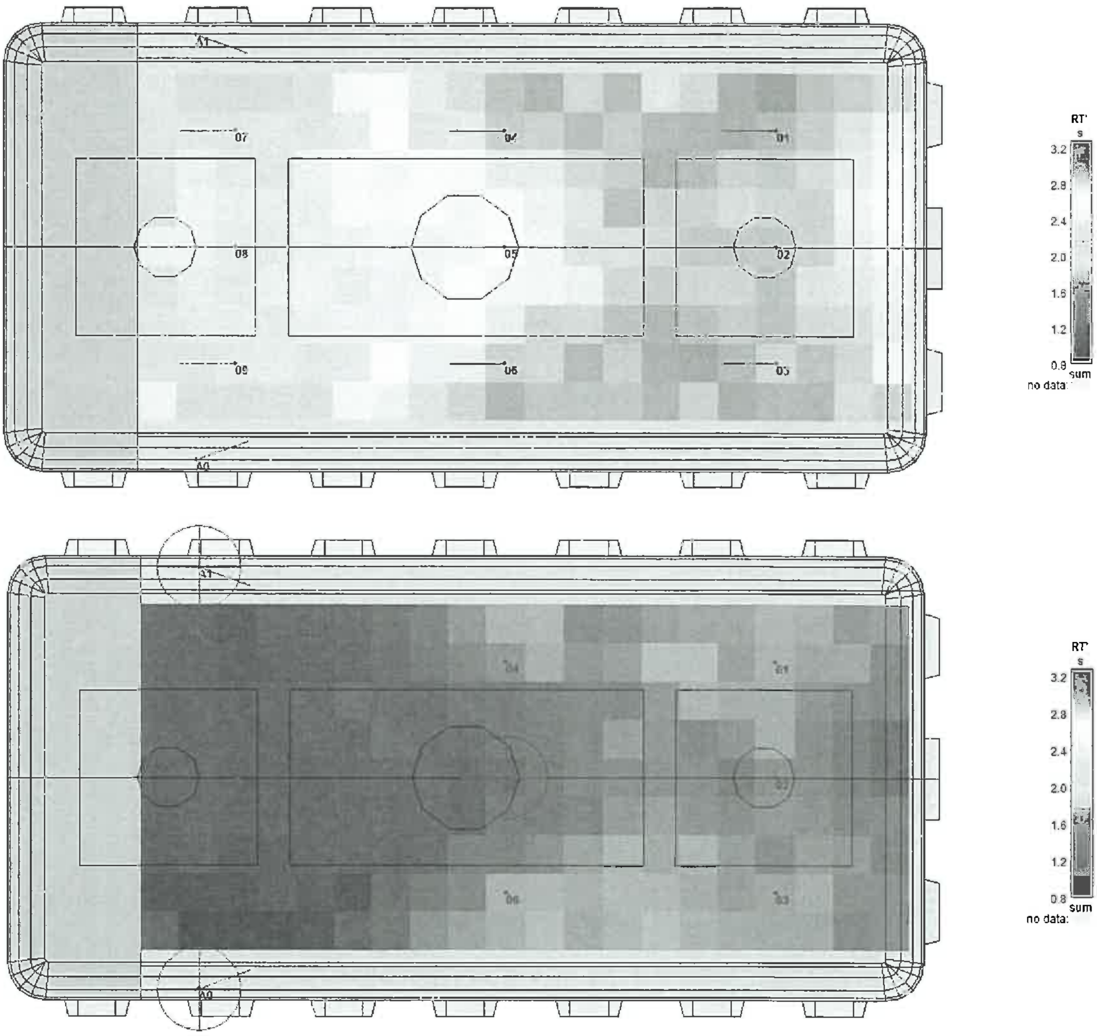

Figure 14: Reverberation Time Before and After Treatment (option A)

5.3 PA SYSTEM TUNING

The specifications of the currently installed PA system appears adequate for the majority of the uses of the hall. The system processor however is not properly configured for the space. Speech intelligibility may be improved by using a dedicated speech tuning for the PA. A second pre-set tuning for music would also be recommended.

With the speakers located either side of the stage, the PA is configured for the performer to be on the stage (audience receives amplified sound symmetrically about their viewing line). If the performer is located on the western wall the amplified sound will have a strong perceived directionality. Further, if the performer is a musician and not using the PA there will be poor lateral reflections (walls a long way away) resulting in a sound that is perceived to have little envelopment.

6.0 RECOMMENDED MODIFICATIONS

With the aim of reducing, and balancing, the town hall ballroom reverberation time, the following is recommended. The modifications bring the room acoustics close to that required for good speech intelligibility but allow some variability so that conditions more favourable to music may also be achieved by retracting the curtains.

- Install 100mm Autex Quietspace panels or similar in the Eastern alcoves and in the lower section of all side wall alcoves.
- Install heavy weight, high drape curtains to the upper level of the eastern and western walls.
- For classical music have the curtains retracted on both sides, and for speech or amplified music have them fully drawn.
- With regards the windows, they are a relatively small area and acoustic blinds offer only mid to high frequency absorption. Such absorption will only increase the frequency imbalance of the reverberation time and have negligible impact on the speech intelligibility. No acoustic treatment is recommended for the windows therefore. Any changes to the blinds are at the architects discretion.
- Tune the PA system for two settings, music and speech. These "tuned" settings are stored as pre-sets for recall at any time.
- When using the PA system, the performer should be on stage and not on the longer side wall.
- Upgrade the sash window glazing to 10mm laminated.
- Seal the sash windows around their perimeter with a silicone sealant.
- Improve the sealing system on the internal glazing leaf .
- Replace the current balcony door set and frame with a heavy door set that is well sealed around its entire perimeter when shut.

7.0 COSTING

The following budget costs have been obtained for the recommended treatments.

TREATMENT	COST
75mm Autex Quietspace white 'nude' panel	\$ 105 per m^2
100mm Autex Quietspace white 'nude' panel	\$ 122 per m^2
75mm Autex Quietspace panel with Vertiface fabric covering	\$ 122 per m^2
100mm Autex Quietspace panel with Vertiface fabric covering	\$ 140 per m^2
Barrisol A30 micro perforated screen, clear, framed	Awaiting Price
Curtains full drape, track mounted	\$ 100 per m^2
Glazing upgrade to 10mm lam	\$ 520 per m^2
Upgraded door set to Balcony	\$ 4,700

Table 7: Budget Cost for Various Treatments