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ACOUSTICAL CORRECTIONS CASE-STUDY FOR OPEN AND CLOSED OFFICES

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Abstract

The owner-occupants of a new three-story office building received office acoustics complaints shortly after moving in. The facility incorporated a two-story atrium-reception lobby, open-plan (cubicle) offices, closed (private) offices, conference rooms and other lounge/break, storage, work and utility spaces. The management collected and categorized staff complaints into groups, including *i)* reverberation and noise in reception lobby, *ii)* speech privacy and intrusive noise in conference rooms, *iii)* occupant activity, speech distraction and annoyance in open plan offices, *iv)* telephone, business machine and computer noise in open plan offices, *v)* miscellaneous transient noises from door closers and other structure borne sources. The building is home to a professional association that deals with issue advocacy, policies, group risk management administration and other services for the members, which creates needs for confidential privacy for members' information and workspace privacy for staff comfort. An acoustical consultant was retained to identify and solve problems, including establishment of acoustical criteria. Minimum and maximum background noise levels and sound isolation thresholds were recommended for various functional spaces. Enclosed office and conference spaces were considered and treated as sound barrier issues, while open-plan office and circulation spaces were considered as configuration and reflection pattern concerns. Background sound spectra and transient disturbances were measured during normal business hours at various locations for comparison with background noise criteria. The types of complaints and their locations were also compared with sound measurements. The consultant developed and recommended a range of barrier, absorber and rearrangement solutions. The facility management developed a mitigation plan for incremental implementation. Not all measures have yet been carried out, but the management reports subjective approval and overall success.

1. Introduction

A new three-story building was constructed for an organization that deals with advocacy, policies, group risk management administration and other services for member organizations. The management and staff both require privacy due to sensitivity of the members' information handled by the organization. The entry reception lobby is a two-story atrium, open to ground level and the floor above. The owner occupants planned and constructed a mixture of perimeter private offices (enclosed), inner-bay open-plan (cubicle) offices, perimeter and interior conference rooms and various other interior rooms for work, lounge/break, storage and support spaces on each of the three floors.

After the agency moved into and adapted to the new office building the management began to receive complaints about reverberation in the atrium reception, perceived loss of privacy, distractions and annoyance in offices and intrusive noise in conference spaces. The management compiled a list of issues reported by various departments. Complaints included corridor activity and conversational noise, transient door closure distractions, sound transmission between enclosed offices and conference rooms, audible business machines and telephone ring tones, and noise transmissions from other remote locations.

2. Initial Office Environment

The owner-occupant organization personnel moved into a newly constructed office building. In addition to normally expected staff adjustments to a new facility, some dissatisfaction persisted. The three-story building has two wings around a central entrance lobby atrium, as shown on the typical floor plan below. Various functional space uses are distributed throughout each floor.

Figure 1. Floor Plan: Office Building Typical Floor Showing Types and Distribution of Spaces.

2.1 Architectural Finishes and Furnishings

The office finishes are typical of North American office spaces, combining closed private and open (cubicle) offices with conference rooms, machine, work and lounge spaces in the core area. Demising partitions are metal stud-framed drywall (plaster board), with some constructed from floor to structural deck above and some extending only up to ceiling elevation. Open-office cubicles are 1.22m (48”) high and partially acoustically absorptive. Floors are generally covered with thin carpet-tiles, except for staff lounges, machine (servers, printers, etc.) and workrooms. Suspended ceilings have lay-in acoustical tiles with moderate absorption. Doors in metal frames have brush pile infiltration seals or small impact pad silencers. Large areas of exterior walls are glazed. Office and conference demising partitions interface window mullions at the partition-wall intersection. Open-office and workroom air-conditioning supply diffusers are located in the suspended ceiling grid. Return air flows through troffers in lay-in light fixtures. Private office and conference rooms have drywall soffits with slot diffusers. Return air flows through gaps above the soffit.

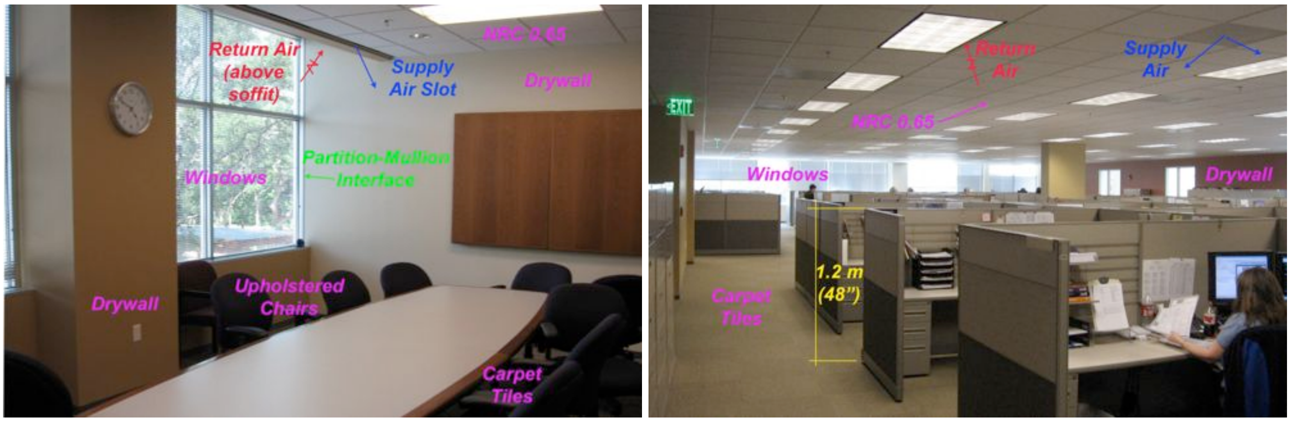

Figure 2. Conference and Private Office Architectural Finishes (left), Open-Office Finishes (right).

Figure 3. Reception Lobby Architectural Finishes (left), Break Lounge Finishes (right).

2.2 Acoustical Issues

The staff and management experienced numerous adjustments, as would be expected. Some post-occupancy issues persisted beyond the initial period of adaptation, of which many were acoustical. The building management compiled an itemized list of specific complaints that were keyed to office floor plans to show locations and distribution of noise complaints. They are described in summary below:

- Reverberation and transient distraction noise in the reception lobby; making it difficult to answer incoming telephone calls or to direct visitors to the correct departments. Distractions included elevator announce chime, footfall impacts on hard floor surface, conversations of parties walking through the lobby and door closure impacts.
- Speech Privacy and distracting intrusive noise in conference rooms; causing loss of confidentiality for sensitive information and speech interference in conference communications. Distractions included conversational speech, telephone/speakerphone use and business machine noise from adjacent offices and occupant speech and activity generated noise from nearby open-offices.
- Corridor and aisle traffic, conversational and activity noise disturbing cubicle occupants in open-office areas. Distractions included people gathering and conversing near conference rooms prior to entering, individuals in aisles speaking over cubicle partitions to open-office occupants and individuals speaking on telephones with loud voices.

- Transient noise distractions disturbing cubicle occupants in open-office areas, including telephone rings, business machines, printers and various computer sounds.
- Transient noise distractions disturbing cubicle occupants in open-office areas, related to building, such as structure borne transmission of impact and machine noise from other spaces, door closure impacts and electronic door latch mechanisms.

The decision was made to retain a consultant to assist with evaluation of acoustical issues and development of mitigation solutions for privacy, distractions, annoyance and background noise.

3. Acoustical Consultation

The consultant recommended acoustical criteria, conducted observations and acoustical measurements in the facility and developed a range of conceptual solutions for client consideration.

3.1 Criteria

Acoustical criteria were recommended, including maximum continuous building systems background noise; RC 30[1] for large conference, RC 35 for private office small conference, RC 40 for reception, work rooms, break lounges and corridors. Neutral spectra, RC (N) should be required. Open-office spaces were recommended to be not less than RC 35 and not more than RC 40, for some speech masking without being uncomfortable. Sound isolation criteria in terms of sound transmission class (STC)[2], similar to Sound Reduction Index (SRI)[3] were recommended, ranging from STC-55 for large conference down to STC-40 for corridor walls, with office, work, machine and other spaces in between. Performance de-rating[4] consideration was incorporated for flanking paths and workmanship.

3.2 Observations and Measurements

Many conditions were observed which appeared to contribute to acoustical dissatisfaction, some unique but many ubiquitous. Background spectrum measurements were conducted in several areas. Although initially contemplated, sound transmission measurements were deferred to avoid office disruption from the loud sound source needed, and ultimately eliminated,

3.2.1 Observations

Observations relating to Acoustical Conditions, Section 2.2, above, were noted:

- Reverberation in the reception lobby: large *volume* space with predominance of hard, acoustically reflective floor wall and ceiling *areas*, which both contribute to reverberation.

$$\text{Reverberation Decay Time}^5\text{: } T = 0.161\ V/a \text{ (Metric), } T = 0.049\ V/a \text{ (English)} \quad (1)$$

Where T = seconds, V = volume in cubic meters and a = absorption in square meters

- Conference room and office privacy: partitions are not adequately sealed at intersections with exterior window mullions. In locations where partitions do not extend above ceilings, return air openings in soffits permit “cross-talk” flanking sound.
- Corridor and aisle traffic, conversational and activity noise: space planning places pre-function gatherings outside conference rooms near open-office workspaces. Ceiling acoustical absorption is inadequate to reduce reflections from aisle to cubicles. Wall and partition surfaces are reflective drywall with no acoustical absorption to reduce reflections.
- Telephone rings, business machines, printers and various computer sound distractions: inadequate ceiling and partition surface acoustical absorption is to reduce reflections between cubicles or along path from workrooms to open-offices.
- Transient impact and machine noise: appears to be transmitted via structure borne paths from other spaces, resulting in sound radiation from partition, door and ceiling surfaces.

3.2.2 Ambient Noise Measurements

Measurements relating to Acoustical Conditions, Section 2.2, above, were also conducted. Statistical (Ln) measurements[6] were made in various functional spaces, including reception lobby, open offices, private office, conference rooms, machine and workrooms, storage and corridor. L90 background levels (sound spectrum during 90% of measurement sample), generally 1-2 minutes, are shown below to compare background levels.

- Acoustical complaints were common in open office areas, except for a single department that installed small, visible, cubicle-mounted sound masking units. The statistical spectrum measurements, Fig. 4, contrast greater variability of sound where background level is quieter, versus open offices with masking, which have a louder background, but less sound level variation. The more consistent noise environment produced fewer complaints in this facility than more variable areas.

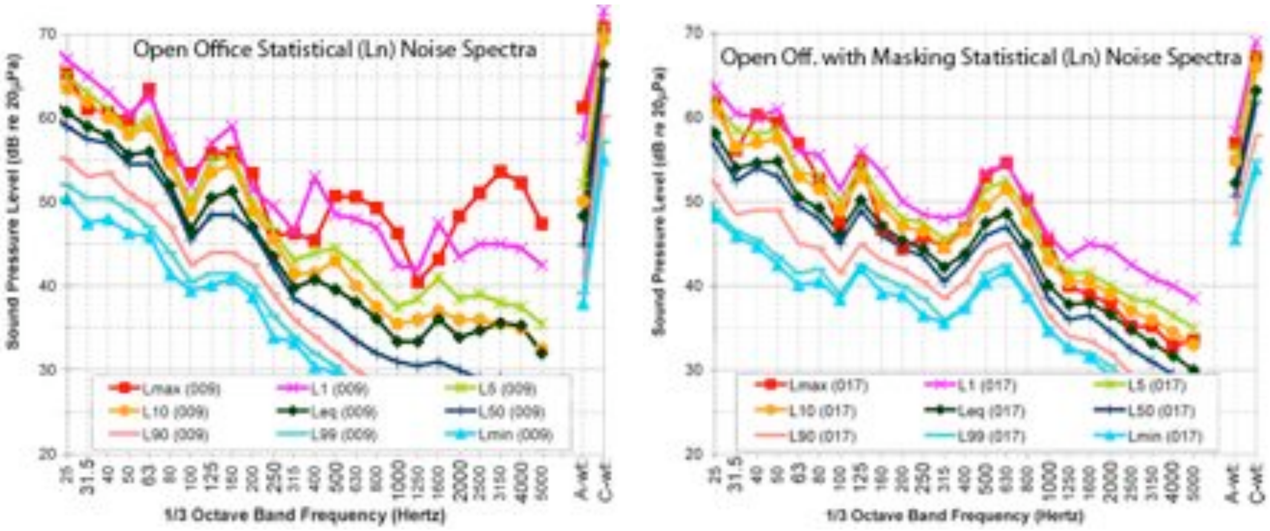

Figure 4. Comparison: Open Office Noise Variation without masking (left) vs. with masking (right).

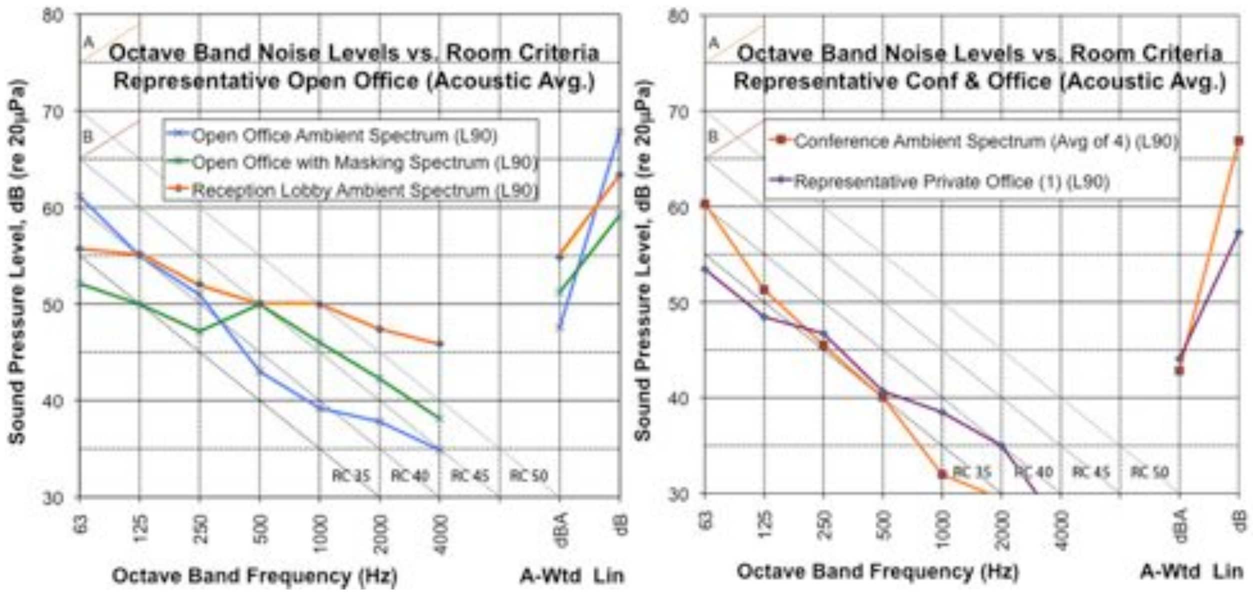

Figure 5. Ambient Noise - Reception Lobby & Open Office (left), Conferences & Private Office (right).

- The L90 ambient noise spectra, Fig. 5 for a typical open office area without masking (blue) is contrasted to the open office area with masking (green). Note increased (masking) sound level in the span of voice frequencies that contributes to speech intelligibility, 500 - 2000 Hz.
- The reverberant reception lobby also has elevated sound level in voice frequencies (orange), Fig. 5, which causes speech interference for receptionist taking phone calls and directing visitors.

- Private offices and conference spaces, Fig 5, generally have moderate sound level in voice frequencies, resulting in good speech intelligibility, but leaving spaces subject to intrusive noise distractions if the demising assemblies permit flanking sound transmission.
- Interior spaces, including conference and work rooms, which are closer to core spaces, have somewhat greater low frequency contributions to ambient sound, while private offices on the building perimeter and open plan offices farther from the core have lower levels of low frequency sound.

4. Recommendations for Acoustical Improvements

Acoustical solutions for reverberation, demising assembly sound transmission, open office transient distractions and structure borne machine and impact noise were developed, based on measurement results versus recommended criteria and observations. Certain practical considerations limited the range of solutions, such as relocating noise sources or receivers in lieu of modifying architectural elements or avoiding modification of demising partitions if correction of flanking paths would provide adequate privacy. No modifications were recommended for building systems and HVAC noise, which, except for room reverberation build-up, were not found to be excessive.

4.1 Room Acoustics – reverberation and reflections

Increase acoustical absorption to decrease build-up of reverberant noise in lobby and other large spaces, including open office areas. This should improve speech intelligibility in reception lobby and improve speech privacy in open office areas.

- Reception Lobby: Mount acoustical panels or finishes, NRC 0.70 minimum, NRC 0.90 preferred, on wall, ceiling and/or soffit surfaces to cover at least 20% of exposed surface area.
- Open office and corridor areas: Replace existing NRC 0.65 ceiling tiles with more acoustically absorptive ceiling tiles, NRC 0.75 minimum, NRC 0.90 preferred. Mount acoustically absorptive panels on large, expansive wall and partition surfaces to reduce reflections.
- Increase ceiling and wall surface acoustical absorption in machine, workrooms and lounges to reduce build-up of impact and transient noise, including conversational noise of occupants.

4.2 Sound Isolation – privacy and freedom from intrusive noise

Isolate sensitive spaces and functions. Determine flanking paths through demising assemblies and treat to reduce transmission.

- Perimeter conference and office demising partition intersections with window mullions: Use acoustical sealant or permanently pliable fire caulk to seal gap between mullion and partition.
- Perimeter conference and office ceiling soffit with return air slot: Block ceiling plenum path:
    - At locations where demising partitions extend to structural deck above, check for holes or gaps in the partition above ceiling level and close or seal with caulking.
    - For Partitions that do not extend above ceiling elevation, either put acoustically lined "boot" over the open return air transfer slot, or erect plenum closure above partition to block the room-to-room sound path, such a mass-loaded vinyl sheet or "head-wall" construction.
- Conference, office, lounges, machine and workroom doors: Install Acoustical seals on heads, jambs and thresholds to replace existing brush pile infiltration seals or "silencer" bumpers.

4.3 Space Planning and Layout Rearrangements

Relocate incompatible spaces and functions. Where personnel queuing, activities and/or materials transportation and staging cause distraction to nearby open-plan offices, determine feasible rearrangements for the purpose of separating distraction sources from sensitive occupant receivers.

- Increase open-office perimeter partitions from 1.2m (48") to 1.6m (60") to reduce lateral paths.

- Relocate conference room door from immediate adjacency with office cubicles to end of room.
- Relocate storage room door in corridor farther from immediate adjacency with office cubicles to alter material transportation route away form offices and reduce number of distracting cart impacts.
- Relocate a small group of open office cubicles away from a conference room door, where pre and post conference gatherings cause distraction, to an unoccupied floor space farther away.

4.4 Mitigate Transient Structure-borne Impact Noise

Reduce noise from door closure impacts. Provide partition and/or door surface damping or de-coupling to reduce transient radiated impact transient noise of automatic door latches (metal-on-metal) and door closure impacts (at jambs).

- Consider changing automatic door latch components or replacing metal actuator with nylon or plastic, or provide minor edge damping of door panel by installing elastomer “bulb seal” to heads and jambs of doorframe.
- Where doors on opposite side of partition from occupied cubicles cause closure impact noise to radiate from drywall partition, remove drywall from cubicle side of partition, install resilient mountings on framing and reinstall drywall. As an alternative, install damped drywall product over existing standard drywall to reduce radiation of impact noise.

5. Owner-Occupant Implementation of Acoustical Recommendations

The building and operations managers reviewed noise control recommendations with regard to cost, scheduling and installation feasibility within an occupied space, i.e., disruption of workers. Several recommendations were implemented. Some were not. Responses to a consultant’s follow-up inquiry indicated implementation.

Table 1. Implementation of Acoustical Recommendations[7]

Category	Implemented?	Successful?	Worth Expense?	Due to Expense?	Due to Disruption?	Deferred to Future?
Room Acoustics						
Lobby Absorption	Yes	Incomplete	Unknown	- - -	- - -	In progress
Conf. Wall Absorp.	Yes	Yes	Yes	- - -	- - -	- - -
Priv. Office Ceiling	No	- - -	- - -	Yes	Yes	No
Open Office Ceiling	Yes	Yes	Yes			- - -
Lounge/Work Ceiling	No	- - -	- - -	Yes	- - -	- - -
Sound Isolation*						
Seal Part’n:Mullion	Yes	Yes	Yes	- - -	- - -	- - -
R/A or Header Wall	Yes	Yes	Yes	- - -	- - -	- - -
Acoustical Door Seals	Yes	Yes	Yes	- - -	- - -	- - -
Rearrangement						
Cubicle Panel Height	No	- - -	- - -	Yes	- - -	No
Relocate Cubicles	Yes	Yes	Yes	- - -	- - -	- - -
Relocate Doors	Yes	Yes	Yes	- - -	- - -	- - -
Impact Damping						
Modify Latches **	Yes	Yes	Yes	- - -	- - -	- - -
Modify Partitions	No	- - -	- - -	Yes	Yes	No
Apply Door Seals	Yes	Yes	Yes	- - -	- - -	- - -

* Sound Isolation recommendations applied to conference rooms and private offices, but not to open-office, work/machine rooms or employee break lounges due to expense.

** In lieu of recommendation, electric strike security latches were changed to magnetic locks.

6. Conclusion

A variety of acoustical privacy, distraction and annoyance problems were reported after new occupation of a mixed closed and open office space. Issues were reviewed and classified by types of sound sources and types of receivers. The physical space was evaluated by observation and acoustical measurement to characterize both spectrum levels of ambient sound and variation of sound level. Various acoustical solutions were developed and categorized as room acoustics for reverberation and reflection control, sound isolation for sound transmission between spaces, space planning for source-receiver adjacencies and impact control for surface radiation damping and/or decoupling of structure borne vibration paths.

The owner-occupant building management reviewed and selected simple and practical solutions, which could be implemented with minimal disruption to the occupied offices. Later post-installation evaluation showed results to be cost effective and successful. Based on the building management's subjective responses, we find that complaints are substantially reduced and the staff is able to work more efficiently with fewer distractions and annoyances that were initially experienced.

This project shows that systematic and comprehensive consideration of multiple noise disturbances can yield good results with moderate cost and minimal interruption or dislocation of occupants.

Acknowledgments

This case study is dedicated to the memory of Michael William Crawford, Director of Operations at Texas Association of School Boards, who worked with the consultant on solution feasibility and provided comprehensive evaluation of solution results.

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[3] International Organization for Standardization, ISO 140–3:1995.

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[6] M.J. Crocker, Determining Human Response to Noise, *Handbook of Acoustics*, M.J. Crocker, Ed., John Wiley & Sons, New York, 1998, Ch. 64, p. 785-786.

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