

Designing Acoustically Successful Workplaces:

CASE STUDIES OF A METHOD FOR PREDICTING SPEECH PRIVACY IN THE CONTEMPORARY WORKPLACE

SUMMARY REPORT, JANUARY 2003

CHARLES M. SALTER ASSOCIATES INC.
CHARLES SALTER, KEVIN POWELL,
DURAND BEGAULT, ROBERT ALVARADO

CENTER FOR THE BUILT ENVIRONMENT

ACKNOWLEDGMENTS

This study grew out of data analyzed from a post-occupancy survey. The insights of Charlie Huizenga and Steve Murray of CBE, and Tamara Dinsmore and Randy Howder of SOM, spurred this effort. The research proposal was developed jointly with Ken Roy of Armstrong World Industries. Many colleagues at Charles M. Salter Associates suggested changes that clarified both the method and text, particularly Jeff Clukey, Jack Freytag, Harold Goldberg, Tony Nash, Michael Toy, Pamela Vold and Brenda Yee. CBE Partner representatives Kevin Kampschroer (US General Services Administration), Ken Roy (Armstrong World Industries), and David Wyon (Technical University of Denmark, formerly with Johnson Controls) offered editorial suggestions that were instrumental in finalizing the text. David Lehrer (CBE) worked tirelessly with us through many revisions, and is responsible for the report's graphic clarity. CBE Director Ed Arens' insight, rigor, and tireless guidance were instrumental through the entire project.

The Center for the Built Environment (CBE) was established in May 1997 at the University of California, Berkeley, to provide timely unbiased information on promising new building technologies and design strategies. The Center's work is supported by the National Science Foundation and CBE's Industry Partners, a consortium of corporations and organizations committed to improving the design and operation of commercial buildings.

CBE's Industry Partners include:

Armstrong World Industries	Taylor Engineering Team: Taylor Engineering, The Electrical Enterprise, Southland Industries, Swinerton Builders
Arup	
California Department Of General Services	Trane
California Energy Commission	U.S. Department Of Energy (DOE)
EHDD Architects	U.S. General Services Administration (GSA)
HOK	
Keen Engineering	United Technologies Corporation
NBBJ	Webcor Team: Webcor Builders, Critchfield Mechanical, Rosendin Electric, C&B Consulting Engineers
Pacific Gas & Electric Co.	
Skidmore Owings And Merrill, LLP	York International Corporation
Tate Access Floors, Inc.	

© Center for the Built Environment (CBE)

A National Science Foundation Industry/University Cooperative Research Center

390 Wurster Hall #1839, Berkeley, CA 94720-1839

tel: 510.642.4950 fax: 510.643.5571

cbe@uclink.berkeley.edu www.cbe.berkeley.edu

TABLE OF CONTENTS

1.0	Introduction	1
2.0	Method	2
3.0	Open Plan Case Study Results	6
4.0	Private Office Case Study Results	14
5.0	Conference Room Case Study Results	22
6.0	Conclusions	30
	Appendix 1: Detailed Method for Speech Privacy Predictor	31
	Appendix 2 Construction Details for Acoustical Privacy	38
	Appendix 3. Survey Methods and Results	39
	Appendix 4: Testing Protocol	41
	References	42

DESIGNING ACOUSTICALLY SUCCESSFUL WORKPLACES:

Case Studies of a Method for Predicting Speech Privacy in the Contemporary Workplace

1.0 INTRODUCTION

In surveys of office environments that measure occupants' satisfaction with their workspace, the intrusion of unwanted sound—noise—vies with temperature as the leading source of dissatisfaction (Harris, 1978, 1991, Sundstrom, 1994, Brill, 2001). Recent research by the Center for the Built Environment supports this finding, with more than 40% of employees responding to CBE's occupant satisfaction survey reporting that workplace acoustics make it harder for them to do their job (CBE, 2001). Moreover, an elevated level of workplace noise has been shown to increase stress, decrease motivation and is associated with risk factors for musculoskeletal disorder (Evans, 2000).

To improve this situation, architects, interior designers, and facilities management professionals need to be able to translate a proposed design into a specific prediction of acoustical satisfaction with the resulting workspace. Over the past 40 years, acoustical consultants have in fact developed such a method. In the late 1950's, engineers at Bolt, Beranek & Newman recognized that a majority of acoustical complaints in offices were related to speech privacy—overhearing unwanted conversations or feeling that one is overheard. Building on research at Bell Labs that correlated a listener's ability to understand words with the ratio between the loudness of a person's voice and the loudness of the background noise, these engineers demonstrated that a listener's *inability* to understand words in a workplace setting is part of this same continuum of signal to noise. They then showed that that a series of objective measurements can establish this ratio and accurately predict an occupant's satisfaction with their speech privacy (Cavanaugh 1962). Over the past forty years, this method for predicting speech privacy satisfaction with has been simplified (Young, 1965), adapted for use in open plan environments (Pirn, 1971) and consolidated into worksheet formats for both open and closed office environments (Egan, 1972). Versions of this calculation procedure have been published in leading texts on acoustical design, including ones by Cavanaugh (1999), Egan (1988), and Salter (1998).

Acoustical consultants have found these speech privacy calculations useful for analyzing design documents, evaluating full-scale prototypes and identifying problems in fully occupied and functioning buildings. These calculation procedures have not, however, been disseminated widely in the architectural and interior design community. Reasons may include unfamiliar measurement units and concepts, the specialized testing equipment required for prototype and *in situ* evaluations, a lack of formal testing validated and illustrated in the context of today's offices, and cost and aesthetics-driven decision making which does not identify the risks of unacceptable acoustics.

This paper presents an updated, simple, easy-to-use version of a *predictive* methodology, the Speech Privacy Predictor (SPP). SPP is intended to help those designing, furnishing or retrofitting open plan and private offices. To illustrate the application of the SPP method, nine case studies are described below. These case studies document acoustical conditions in an office building where the Center for the Built Environment had previously conducted an occupant survey. In layout and utilization, this building is representative of a typical modern office—large open plan areas, ubiquitous telephones with built-in speakerphones, distributed common areas, and widespread use of computers. It is also typical of the acoustical shortcomings of modern offices: CBE’s occupant satisfaction survey had detected significant occupant dissatisfaction with speech privacy.

Each case study is designed to demonstrate how the SPP calculation is performed. The case studies evaluate the reliability of the SPP method, by comparing predicted results with measurements of actual acoustic conditions as well as the subjective level of acoustic dissatisfaction reported by those who had taken the CBE Survey.

Results of these comparisons show broad agreement between the predictive tool, measured acoustic conditions, and surveyed employee dissatisfaction. The SPP method therefore appears to be a viable tool for designing to achieve good *acoustical* environments. This finding is especially noteworthy because while poor speech privacy has been shown to reduce worker motivation, interfere with concentration and compromise the security of meetings and confidential discussions, retrofitting office spaces with poor acoustic performance is often an expensive and disruptive solution.

2.0 METHOD

2.1 Building Selection

To illustrate the application of the SPP method, and evaluate its effectiveness as a design tool, a series of case studies were conducted in a building where the Center for the Built Environment had conducted a Post Occupancy Evaluation Survey.¹ This Class-A office building was constructed in 1980 for its current owner, and contains 650,000 gross square feet of office space. The building’s layout is typical of the modern office: 15% of gross space is used for enclosed private offices and conference rooms, with the remainder used for open plan workstations, common areas, lobbies, circulation, and a variety of other operations. Office equipment is also characteristic of the modern workplace: ubiquitous telephones with built-in speakerphones, computers on nearly every desktop, broad distribution of laser printers, and centrally located areas for photocopying.

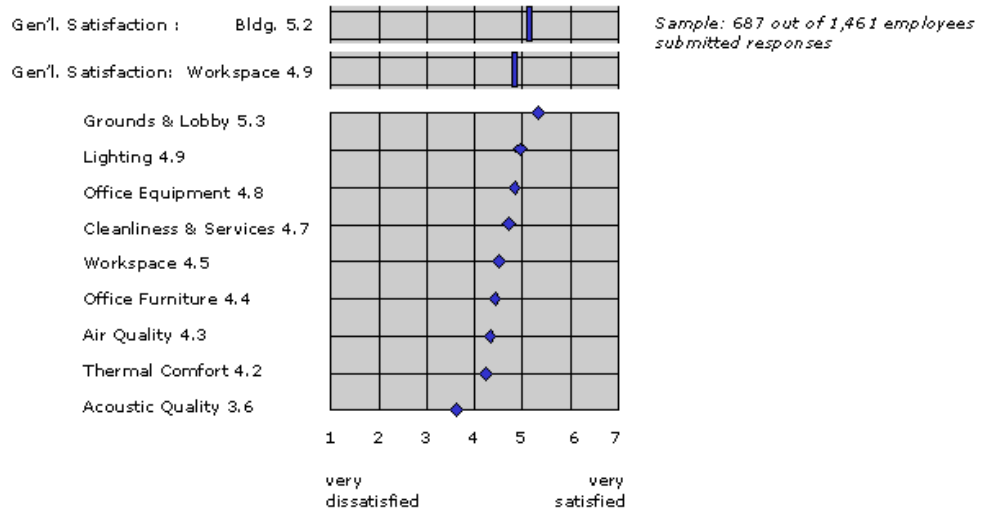
While nearly two-thirds of the 687 respondents reported overall satisfaction with their workspace, and nearly three-quarters of respondents expressed overall satisfaction with the building, CBE’s survey had detected significant dissatisfaction with acoustical conditions.² In contrast to pluralities reporting that lighting, air quality, temperature,

¹ This survey was administered in January 2001, and asked occupants to rank their satisfaction with a number of attributes of their building. Questions ranged from building-wide attributes, such as the perceived quality of the grounds, lobby and cleanliness, to specific conditions in the occupant’s work area, such as lighting, office equipment and thermal comfort. The survey’s protocol requires that specific information about the building, including its owner, location and identifiable physical attributes be kept confidential. An overview of the survey’s structure, how the survey was produced and implemented, as well as key acoustical findings is reproduced in Appendix 3.

² Of the nine major categories surveyed, only acoustical conditions got more votes of dissatisfaction than satisfaction

office equipment, and furniture made it *easier* to get their jobs done, 46% of building occupants reported that the overall noise level in their workspace made it *harder* for them to get their job done.³

Table I
Summary of
Post Occupancy
Evaluation Results by
Category



This level of acoustic dissatisfaction relative to other building attributes is consistent with nearly two-dozen similar occupant satisfaction surveys CBE has administered over the past three years. It is nonetheless puzzling, because the surveyed building is owner-occupied, constructed less than twenty five years ago as a headquarters building with premium finishes and materials, and has a responsive and involved facility management staff. Moreover, dissatisfaction is not limited to occupants working in open-plan areas: more than a third of respondents in the enclosed private offices also expressed dissatisfaction with their speech privacy. Nor can acoustical dissatisfaction be attributed to unusual or specialized work processes, overcrowded conditions, rapid growth or management turbulence: the majority of the building’s occupants are managerial and professional workers engaged in the types of ‘knowledge work’ characteristic of many modern business enterprises, and the building’s owner/occupant has not engaged in expansion, acquisition or layoffs in the five years before the survey. Would the SPP method have predicted this level of acoustic dissatisfaction?

³ Question 30.4. “Overall, does the noise level in your workspace make it easier or harder to get your job done?”

2.2 Selection of Case Study Locations

CBE's research protocol allowed us to filter data by floor and office type (enclosed/open plan). We then worked with the building's facility manager to identify floors that had a representative range of acoustic and work conditions, and responses that tracked with the overall building.⁴

OPEN PLAN CASE STUDIES.

The facility manager noted that the physical layout of workstations in the case study floor were representative of those distributed throughout the facility, consisting of standard 8 foot by 10-foot cubicles, enclosed by Herman Miller Action Office I, a 62-inch high acoustical partitions.⁵ The ceiling finishes were also representative of those found throughout the building, consisting of 2-x 2-foot mineral-fiber ceiling tiles⁶ with a noise reduction coefficient (NRC) of 0.55⁷ and a ceiling attenuation class (CAC) of approximately 35.⁸ Floors were finished with standard carpet tiles.

PRIVATE (ENCLOSED) OFFICE CASE STUDIES.

Although the facility manager reported that, building-wide, private offices varied more in size than did open-plan workstations, the private offices we studied were standardized at 10 feet wide by 15 feet deep, and were located in the building core. These offices were constructed of uninsulated steel stud partitions faced with one layer of gypsum board on each side. A solid core wood door and a five-foot expanse of floor to ceiling glazing were part of the corridor-facing wall. Partitions terminated at the underside of the suspended acoustic tile ceiling. Ceiling and floor finishes were identical to open plan areas.

CONFERENCE ROOM CASE STUDIES

Narrative comments revealed frequent complaints of sound transfer between private offices and conference rooms, and between the conference rooms themselves. We conducted case studies in three representative conditions: between a large conference room and a private office, between a small conference room and a private office and between a small conference room and a large conference room. Like private offices, conference rooms were located in the building core, and shared the same modular geometry (large conference rooms were 15 feet by 20 feet, small conference rooms 10 feet by 15 feet). Construction assemblies and finishes for conference rooms were nearly

⁴ Survey results for the selected case study locations showed a level of speech privacy dissatisfaction that was within 10% of the building-wide average response for open plan areas and within 2% of the building-wide average response for the private offices.

⁵ The building occupant has adopted a new standard of 8' x 8' cubes, but at the time of the survey, only limited areas had been redesigned.

⁶ A portion of the private offices we studied received a higher performing ceiling as part of a 1998 redesign. This ceiling did not produce a noticeable effect in survey data. The open plan case studies were conducted on a floor with a ceiling height of 13 feet while other floors had a 9-foot ceiling height. Again, we were not able to detect significance in survey data.

⁷ NRC measures the average percentage of noise a material absorbs at four frequencies across the audible spectrum. This key measure of absorption of general office noise is expressed as a single value percentage.

⁸ CAC rates a structure's efficiency as a barrier to airborne sound at 16 speech frequencies. It is an especially significant measure in providing acoustic privacy between adjacent work areas, where sound can penetrate plenum spaces and carry to other spaces. CAC is stated as a minimum value; CAC minimum 25 is acceptable in open plan offices, while a rating of minimum 35 or 40 is preferred for closed offices. (Reference: ASTM E 1264)

identical to those found in private offices, including the same acoustic tile ceilings, carpeted floors and walls of gypsum board on steel studs, with the corridor facing wall including a solid core door, and an expanse of floor to ceiling glass. No sound absorbing panels were installed on any walls.

2.3 Application of the SPP Method

To establish the ratio of intruding speech to the ambient background noise the SPP method considers a pair of adjacent spaces, the *source space*, where conversation is occurring, and the *receive space*, where speech privacy is being measured. The calculation procedure simply involves subtracting *isolation factors* from *source factors*, in order to produce a single number rating called *sound excess* for the receive space. Speech-privacy satisfaction can then be plotted as a function of the single number sound excess rating, as illustrated in Figure 2.

To illustrate the SPP method’s application and evaluate whether it would have predicted the unsatisfactory conditions detected by the CBE survey in both open and enclosed office settings, a SPP predictive calculation procedure was performed for each case study location⁹. These calculations drew on the following information: workstation layout, room surface treatments and materials, partition heights and construction, voice levels, room sizes, and background noise. To test the reliability of the assumed values for the variables involved in these calculations, a series of acoustical measurements and field observations of occupant behavior were also made in each case study location. Predicted and measured results were described in terms of the level of satisfaction predicted by the SPP method, and congruence of these ratings with the CBE survey’s overall finding of occupant satisfaction with speech privacy was evaluated. Table 2 provides an overview of the research design. The worksheets and detailed description of the SPP method’s variables and calculation method are summarized in Appendix 1.

Table 2: Overview of Research Design

	PREDICTED VALUES (FROM DESIGN DOCUMENTS)	MEASURED VALUES (FROM FIELD OBSERVATION & MEASUREMENT)
SOURCE FACTORS		
A. Sum Source Factors	(value)	(value)
ISOLATION FACTORS		
B. Sum Isolation Factors	(value)	(value)
SOUND EXCESS		
Source Factors minus Isolation Factors (A-B)	(value)	(value)
Predicted Level of Acceptability	(value)	(value)

⁹ Testing protocol is described in Appendix 4.

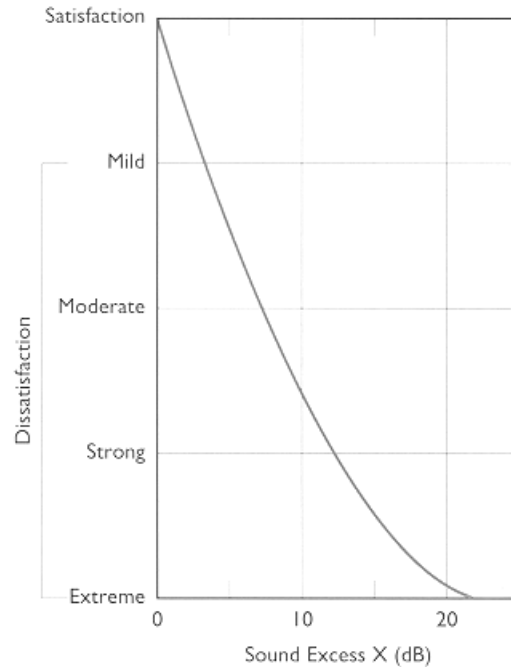


Figure 2: Levels of Speech Privacy Acceptability, per Cavanaugh

SOUND EXCESS	LEVEL OF DISSATISFACTION
+3	Mild
+7	Moderate
+12	Strong
>+20	Extreme

3.0 OPEN PLAN CASE STUDY RESULTS

Three open plan case studies are described below. Overall, we found that the level of dissatisfaction predicted by the SPP method correlated with the dissatisfaction with speech privacy expressed in the CBE survey and with measurements of actual acoustical conditions. There was, however, more spread between predicted and measured SPP values than in case studies of private offices and conference rooms. We attribute this spread largely to the greater range of conditions that the SPP procedure must account for in an open plan environment. In this case, better than predicted noise reduction between workstations was achieved by a combination of a partition product that performs better than expected, a greater than usual number of absorptive surfaces, and a noisy HVAC system in one of the three measured locations.



Had these case study locations originally been evaluated with the SPP method, a level of background noise too low for normal speech privacy given the dense spacing of cubicles would have been predicted. Although it may seem counter-intuitive, the most effective way to improve speech privacy in this condition is to introduce background noise in a controlled manner. This is commonly referred to as *sound masking*, and is typically achieved by placing loudspeakers in the ceiling plenum. These loudspeakers produce evenly distributed noise similar to the

sound of air coming out of an air register. Based on this finding, a sound masking system has been installed in this area as a retrofit, and is currently being tuned and adjusted. Initial response has been positive.

Two additional design issues would have been identified as likely to contribute to a speech privacy problem. First, a lack of appropriately designed and distributed meeting and conference spaces leads occupants to hold impromptu meetings in their cubicles, even though occupants are aware that this will disturb their neighbors. The second design issue that would have been identified is that grid-like layouts of cubicles create an extensive network of circulation ‘streets’ where casual conversation is likely to occur and disturb other occupants. Both of these behaviors were, in fact, observed as contributing significantly to the speech privacy complaints in the space.

FINDING 1: In open plan settings with underfloor air distribution or traditional variable air volume overhead ventilation systems (HVAC), the background sound level will be too low to achieve “normal” speech privacy. In these environments the background sound can be augmented with sound masking system. Adequate absorptive surfaces such as acoustical ceiling and partitions and a carpeted floor will also be required.

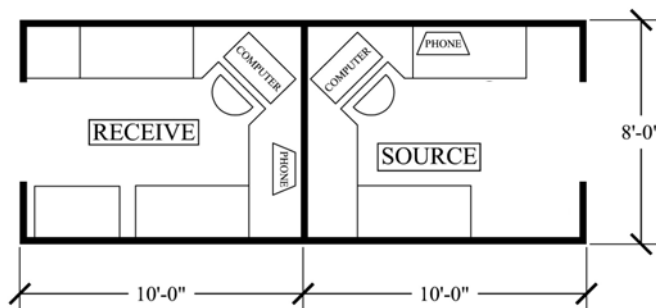
FINDING 2: In open plan offices, there should be a distribution of enclosed ‘teaming’ and conference spaces, located proximate to the work area, with good visual access to and effective acoustical separation from the open plan work area to accommodate both formal and informal group conversation.

FINDING 3: In open plan settings a ‘boulevard’ and ‘cul-de-sac’ layout should be used to ensure that impromptu casual conversation occurs away from workstations.

3.1 Case Study I: Open Plan Workstation to Workstation

In this case study, we observed work-related conversation occurring between two co-workers in a cubicle adjacent to the evaluation space. Even though a nearby HVAC supply air diffuser was mis-adjusted, creating additional background noise and improving the signal-to-noise ratio in this workspace, the occupant commented, “I am disturbed by conversations in adjacent cubes, it makes it difficult to concentrate”.

Plan:
Case Study I



Although the employees in the adjacent cubicle were maintaining a respectfully quiet conversational voice, it is difficult to accommodate any meeting activity in an open plan workstation. Even if there were a sound masking system, this level of conversational activity given this cubicle spacing would produce “moderate dissatisfaction.”

Narrative comments in the CBE survey offer additional insight into this condition:

We currently don't have a conference room; therefore, meetings are held next to my cubicle. I can usually ignore that noise, but it is extremely difficult and disconcerting to know that the people in these meetings hear my phone calls.

It is very hard to concentrate when people are talking, having meetings, in surrounding cubes.

The other group next to us is very chatty and loud. They are not programmers/developers so they may not need the same amount of quiet I do to complete my job.

The biggest illusion of cubicle dwelling is the illusion of privacy. People sometimes forget that just because they cannot be seen does not mean that they cannot be heard.

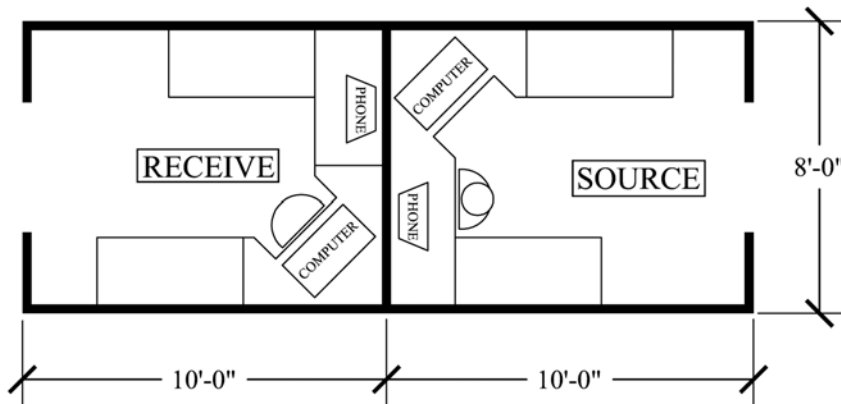
Case Study I

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Low Voice	54	Conversational	60
B. Speech Privacy Criterion	Normal	9	Normal	9
Sum Source Factors		63		69
ISOLATION FACTORS	PREDICTED		OBSERVED	
C. Distance: Source to receiver (from table)	6 feet	5	N/A	
D. Barrier Noise Reduction (from table)	Source to barrier: 3' Receiver to barrier: 3' Break in line-of-sight: 1'	8	N/A	
C+D Noise Reduction (measured <i>in situ</i>)		13	Measured	17
E. Background Noise (dBA, receiving cubicle)	Typical: Open Plan (without sound masking system)	40	Measured (Under HVAC return)	42
Sum Isolation Factors		53		59
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+10		+10
Predicted level of acceptability		Strong dissatisfaction		Strong Dissatisfaction

3.2 Case Study 2: Workstation to Workstation

In this case study, we observed no unusual activities. The occupant of this cubicle and others nearby spoke in low speech levels into their telephones. This voice level is characteristic of the type of speech behavior that is most successfully accommodated in an open plan environment. The very low level of background noise created unsatisfactory speech privacy conditions. The occupant commented, "I can hear others talking but I tune it out. No one can use a speakerphone because it would bother other people". SPP calculation would suggest that the introduction of 8 bBA of additional background noise through a well-tuned sound-masking system would create acceptable acoustical conditions for this partition system and cubicle layout, assuming the workgroup would consistently maintain the low voice level we observed.

Plan:
Case Study 2



Narrative comments in the POE survey offer additional insight into this condition:

Some talking could be classified as productive (one can learn a lot just by overhearing relevant conversations).

I wear hearing protectors (like the jack-hammer guys) when I really want complete concentration. It's amazing how noisy the area can be - not the decibel level, but a number of surrounding cubicles with conversations going on.

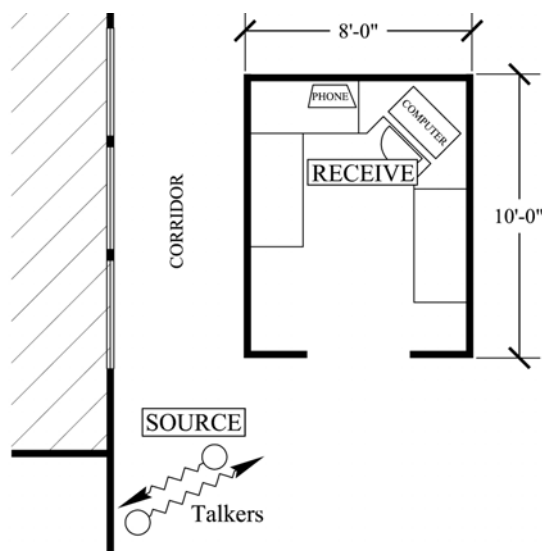
No private work conversations can ever be held in my work area because of the lack of privacy.

Case Study 2

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Low Voice	54	Low Voice	54
B. Speech Privacy Criterion	Normal	9	Normal	9
Sum Source Factors		63		63
ISOLATION FACTORS	PREDICTED		OBSERVED	
C. Distance: Source to receiver (from table)	6 feet	5	N/A	
D. Barrier Noise Reduction (from table)	Source to barrier: 3' Receiver to barrier: 3' Break in line-of-sight: 1'	8	N/A	
C+D Noise Reduction (measured in situ)		13	Measured	17
E. Background Noise (dBA, receiving cubicle)	Typical: Open Plan (without sound masking system)	40	Measured	37
Sum Isolation Factors		53		54
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+10		+9
Predicted level of acceptability	Moderate-strong dissatisfaction		Moderate-strong dissatisfaction	

3.3 Case Study 3: Corridor Talkers to Workstation

In this case study, we observed an informal conversation occurring between two co-workers from a different work unit taking place in the adjoining corridor. While conversation was occurring, a nearby employee was engaged in technical work requiring analytic concentration. Although the corridor conversation was not loud, it was not possible to accommodate the type of casual, informal conversation that often occurs in circulation spaces (and which is typically one of the desired outcomes of the less formal open space environment) adjacent to a workstation where an occupant's job required concentration. The occupant commented: "People talk in the corridor near my workstation, it can be distracting."



Plan:
Case Study 3

In this case, the introduction of increased background noise would improve but not remedy the situation. A change in occupancy to a person not requiring speech privacy would be recommended for this area. If redesign could be considered, segregating 'boulevards' of office-wide circulation from 'cul de sacs' offering workstation access to employees in a given workgroup would be recommended.

Three narrative comments in the POE survey offer insight into this finding:

Corridors aren't just around the elevator, etc. but throughout the work area and people stop and talk everywhere. The sound just carries through open space.

The floor plan is arranged so all the traffic goes past the open side of the cubicles. Better design would come up with an alternative route.

I sit near a row of offices. The managers have lots of people in and out of their offices, as they should, but the way the offices are set up, they reflect sound out into the open office. It's very distracting.

Case Study 3

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Conversational	60	Conversational	60
B. Speech Privacy Criterion	Normal	9	Normal	9
Sum Source Factors		69		69
ISOLATION FACTORS	PREDICTED		OBSERVED	
C. Distance: Source to receiver (from table)	12'	10	N/A	
D. Barrier Noise Reduction (from table)	Source to barrier: 6' Receiver to barrier: 6' Slight break in line-of-sight'	5	N/A	
C+D Noise Reduction (measured <i>in situ</i>)		15	Measured	12
E. Background Noise (dBA, receiving cubicle)	Typical: Open Plan (without sound masking system)	40	Measured (under HVAC return)	42
Sum Isolation Factors		55		54
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+14		+15
Predicted level of acceptability	Strong dissatisfaction		Strong dissatisfaction	

4.0 PRIVATE OFFICE CASE STUDY RESULTS

Three case studies of private offices are described below. Here, too, we found that occupant dissatisfaction predicted by the SPP method correlated broadly with the overall speech privacy dissatisfaction detected in the CBE survey. Moreover, predicted values calculated from design document data corresponded well with values derived from measurement.

Had the design originally been evaluated with the SPP method, a series of options could have been iteratively explored. This process would have begun by identifying employees requiring “confidential” speech privacy and those requiring “normal” speech privacy. Construction assemblies that could achieve the required levels of speech privacy would have then have been recommended. These assemblies would likely have included acoustically upgraded wall construction, and details minimizing the sound transfer between offices where the wall terminates at the underside of a continuous, suspended ceiling. Additional acoustic details to minimize sound leaks at wall penetrations and floor/ceiling connections, as well as methods to minimize the ‘cross talk’ that occurs from unlined ducts running between offices would also have been recommended.

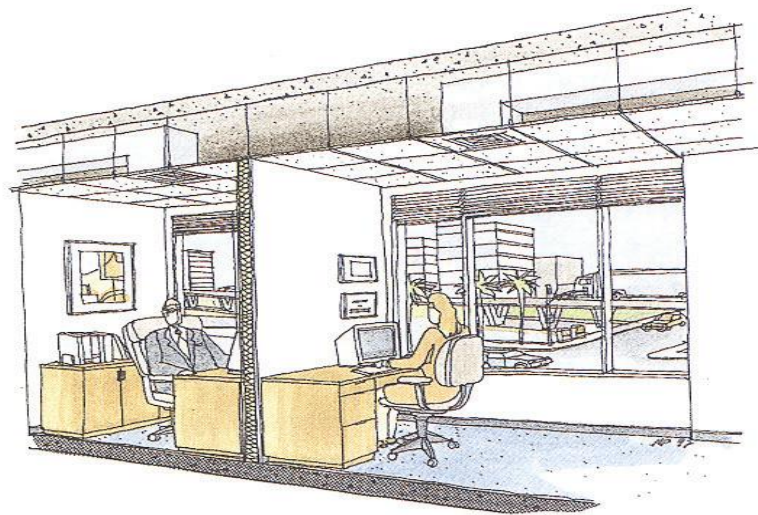


FINDING 1: In standard private offices (100-200 square feet) where ‘normal’ speech privacy is desired and speakerphone use limited, an ordinary steel stud ceiling-height wall can be used if the A-weighted background noise level is at least 40 dB. In a contemporary office building with carpeted floors, a suspended acoustical ceiling, and VAV or underfloor HVAC systems, this level of background noise is likely to be achieved with the installation of a sound masking system. Alternatively, “normal” speech privacy can be achieved in standard private offices with an acoustically upgraded wall assembly.

FINDING 2: In a similar office setting where a where a speakerphone is frequently used, a “confidential” level of speech privacy is required, and a more typical background noise level of 35 dB is desired, an acoustically rated, slab-to-slab partition wall is required.

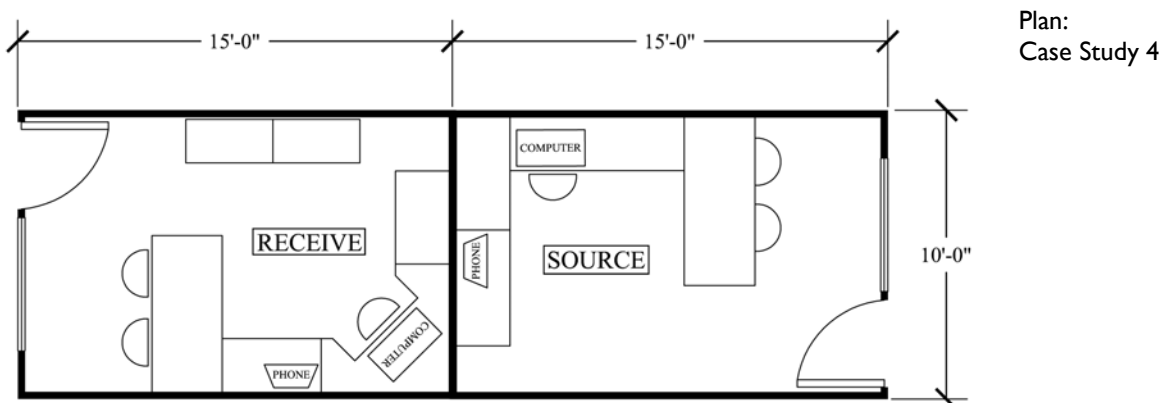
FINDING 3: Speakerphone use should be specifically considered and accommodated in either the acoustical design of private offices or in nearby spaces such as specially designed ‘phone booths’ and conference rooms.

‘Normal’ speech
privacy provided by
ceiling height
partition and sound-
rated ceiling



4.1 Case Study 4: Private Office to Private Office

In this case study, we observed speakerphone use in the office adjacent to the evaluation space. The occupant using the speakerphone later told us, “walls are thin. I know my voice carries, and I am concerned that my neighbors can hear me”. A well-known psycho-acoustic feedback mechanism describes the tendency of people to raise their voice when they experience difficulty comprehending the person(s) they are speaking to.¹⁰ In an office setting, this frequently occurs when people use speakerphones.¹¹ In the past, private offices have typically been designed to provide normal to confidential speech privacy for informal conversation between two or three people. This voice level is lower than that typically used by speakerphone users. Because speakerphones have become increasingly widespread in office settings in recent years, an organizational decision should be made regarding their appropriate use. One possibility is to restrict speakerphone use to conference rooms and/or specially designed rooms, sometimes referred to as ‘phone booths’. Alternatively, speakerphone use within an office can be accommodated by using an acoustically rated construction that will provide the required level of speech privacy for this voice level.



The following narrative comments in the CBE survey offer additional insight into this finding:

[I am dissatisfied with the noise level because] several folks use their speakerphones rather than using a conference room.

¹⁰ It is well known that the presence of noise produces an increase in vocal levels. People's systematic speech modifications during noise are an automatic normalization response called the "Lombard effect". During noise, people increase their volume and reduce their peaking rate and change both their pitch and articulation, especially for vowels. Lombard (1911), Junqua (1993).

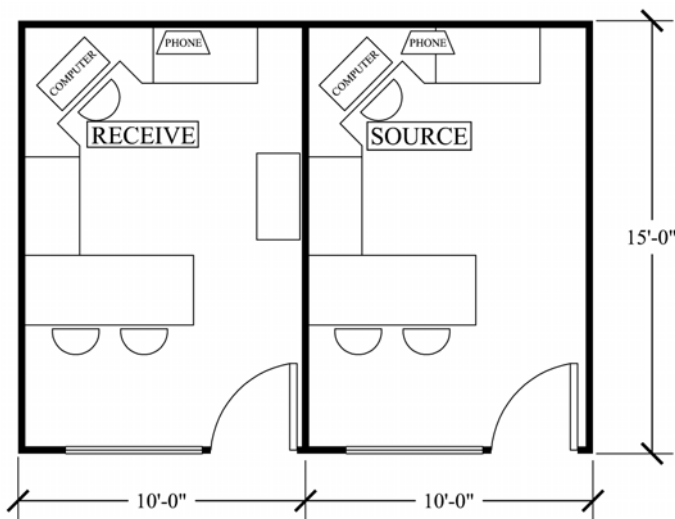
¹¹ Among the causes of poor comprehension: the lack of spatial imaging associated with a monaural source, the overall lack of fidelity in the telephone speaker, and in the case of conference calls, typically poor audibility of some parties to the conversation.

Case Study 4

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Raised	66	Raised	66
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq. ft.	6	150 sq. ft.	6
Sum Source Factors		87		87
ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	Measured	39
E. Effect of Receive Room (from table)		2		NA
F. Background Noise (dBA, receiving room)	Typ.: Private Office	35	Measured	33
Sum Isolation Factors		76		72
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+11		+15
Predicted level of acceptability		Strong dissatisfaction		Strong dissatisfaction

4.2 Case Study 5: Private Office to Private Office

In this case-study, we observed no unusual activity in the adjacent office or open plan area. The occupant of the evaluation space complained, “I have quiet neighbors, but I can hear talking from the offices on both sides of me. It’s not that I can hear what they are saying, but that I can hear that people are talking, and it’s distracting”. The level of speech privacy desired by this occupant, inaudibility, is not ordinarily provided in private offices.



Plan:
Case Study 5

It should also be noted that a private office achieves its rated speech privacy only with its door closed. With its door open, speech privacy will be only marginally better than in the surrounding circulation space/office areas. Exacerbating the potential for disturbance by conversation from surrounding areas, private offices are typically designed to have a level of background noise approximately 10dBA below open plan areas. For these reasons, private offices have traditionally been buffered by an administrative space, or placed within a workgroup where overheard conversation is viewed as a benefit of an ‘open door policy’.

The following narrative comments in the CBE survey offer additional insight into this finding:

The area is noisy and it is sometimes difficult to concentrate unless I close my door. Closing my door contradicts my open door policy.

I can hear conversations in the surrounding offices sometimes. It is annoying.

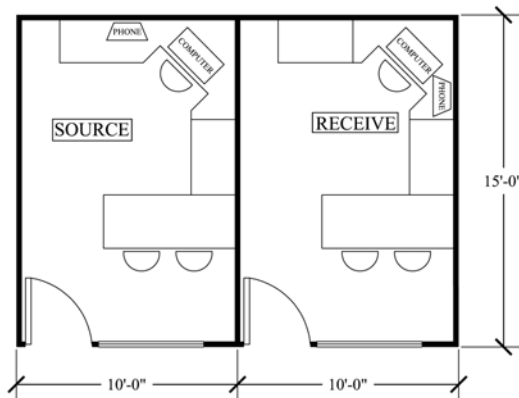
Case Study 5

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Conversational	60	Conversational	60
B. Speech Privacy Criterion (constant)	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq. ft.	6	150 sq. ft.	6
Sum Source Factors		81		81
ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	Measured	37
E. Effect of Receive Room (from table)		0		NA
F. Background Noise (dBA, receiving room)	Typ.: Private Office	35	Measured	38
Sum Isolation Factors		74		75
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+7		+6
Predicted level of acceptability		Moderate dissatisfaction		Moderate dissatisfaction

4.3 Case Study 6: Private Office to Private Office

As in Case Study 5, we observed no unusual activity in the adjacent offices or open plan areas. In contrast to Case Study 5, however, the occupant of this evaluation space appeared substantially less sensitive to the intrusion of speech. The occupant expressed concern, however, that sound was traveling through the HVAC vent: “I’m generally satisfied. But sometimes I can hear conversation in adjacent offices. Sound seems to travel through vents”

Plan:
Case Study 6



All case-study private offices and conference rooms were constructed with walls that extend only to the underside of a continuous suspended ceiling. Although this wall assembly is less expensive than extending the walls from slab-to-slab, the common ceiling plenum becomes a ‘flanking path’, a way for sound to transfer into the adjacent space by moving around the intervening partition. Other common flanking paths include electrical outlet boxes in the common partition, recessed lighting fixtures in the ceiling, connections at the intersection of one partition with another or with a window mullion, and through shared, unlined ventilation ductwork. In all six case studies of private offices and conference rooms, we found sound leaks at the connection between the ceiling and the partition wall, and cross talk at HVAC supply and return air grills

The following narrative comment in the CBE survey offers additional insight into this finding:

Voices magnify and sound louder in my office than they do outside my office.

Case Study 6

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level (dBA)	Conversational	60	Conversational	60
B. Speech Privacy Criterion (constant)	Confidential	15	Confidential	15
C. Effect of Source Room (from table)	150 sq. ft.	6	150 sq. ft.	6
Sum Source Factors		81		81

ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition Rating (STC or NIC)	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	Measured	38
E. Effect of Receive Room (from table)		0		NA
F. Background Noise (dBA, receiving room)	Typ.: Private Office	35	Measured	36
Sum Isolation Factors		76		74

SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+7		+7
Predicted level of acceptability		Moderate dissatisfaction		Moderate dissatisfaction

5.0 CONFERENCE ROOM CASE STUDY RESULTS

In the CBE survey respondents identified the intrusion of conference room noise into adjacent meeting spaces and private offices as a significant problem. In the three conference room case studies described below, the source of this problem is clear: as part of the office space's modular design, conference rooms are fashioned from the same wall assemblies and floor and ceiling finishes as private offices. Conference rooms, of course, typically accommodate activities where a louder voice level is used than occurs in a private office. Therefore, a wall assembly that is adequate for a private office is not likely to work well for a conference space.

Had these conference room designs been evaluated with the SPP method at the design stage, acoustically improved wall constructions would have been recommended. An adequate acoustical design would also include details for minimizing sound leaks and the 'cross talk' between conference rooms and adjacent spaces connected by unlined ducts and shared ceiling plenums. Sound absorbing wall treatments and upgraded ceilings would likely have also been recommended to minimize reverberation and the build-up of sound within these rooms.



FINDING 1: Contemporary office design emphasizes flexibility. Wall and ceiling constructions that will provide normal speech privacy in private offices are not likely, however, to produce acceptable results given elevated voice levels and increased privacy requirements of a conference/meeting space.

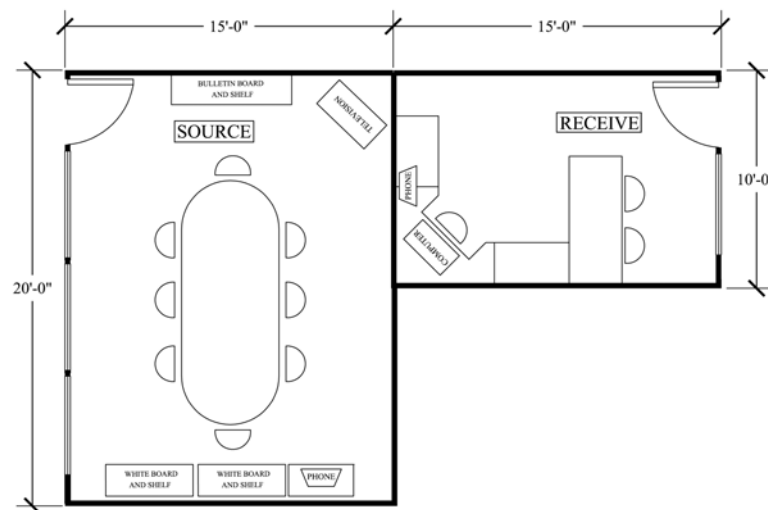
FINDING 2: Some conference rooms are specifically designed to accommodate teleconferencing and audio-visual presentations. These spaces must also be designed to provide an appropriate level of acoustical privacy that allows these rooms to operate without disturbing occupants in adjacent spaces.

Ceilings and partitions need to provide adequate sound insulation for group conversation in conference rooms



5.1 Case Study 7: Large Conference Room to Private Office

In this case study, we investigated the level of privacy between a large conference room and the occupant in an adjacent office. Although we did not observe the conference room in use, the presence of audio-visual equipment in this room suggests that the room supports presentations to an assembled group. When speaking to a group, a presenter typically uses a “raised” to “loud” voice level. The room itself lacked absorptive materials on its walls, contributing to a reverberant sound field (sound reflected by the room’s surfaces rather than being absorbed by them). Testing showed that the acoustical performance of the wall assemblies were the same as for private offices.



Plan:
Case Study 7

The following narrative comments in the CBE survey offer additional insight into this finding:

I often hear noise coming from other conference rooms.

Some conference rooms that have shared walls with offices carry sounds from these offices where you can hear every conversation in the office and vice versa.

There is no sound proofing between my office and the conference room. Thus, I can hear conversations, loud laughter, and meeting proceedings. All of this sometimes drives me from my office.

Case Study 7

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level	Loud (Presentations)	72	Loud (Presentations) ¹²	72
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room	300 sq. ft.	2	300 sq. ft.	2
Sum Source Factors		89		89

ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition: STC or NIC	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	Measured	39
E. Effect of Receive Room (from table)		5		NA
F. Background Noise (dBA, receiving room)	Typ.: Private Office	35	Measured	38
Sum Isolation Factors		79		77

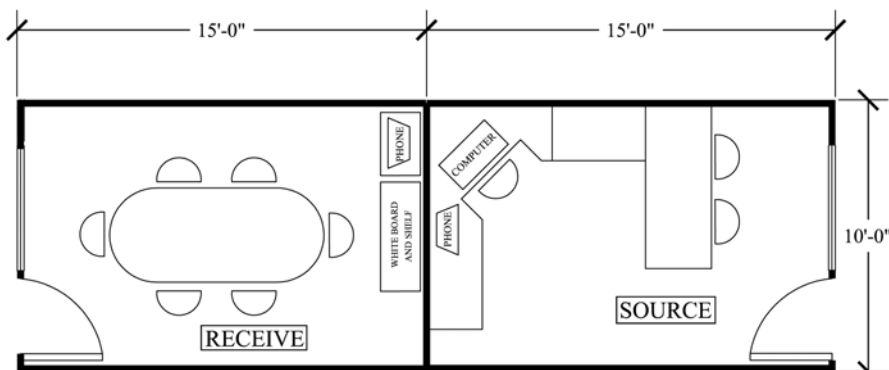
SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+10		+12
Predicted level of acceptability		Strong dissatisfaction		Strong dissatisfaction

¹² No conference was taking place, this value was predicted

5.2 Case Study 8: Small Conference Room to Private Office

In this case study, we investigated the level of privacy between a small conference room and the occupant in an adjacent office. Although we did not observe the conference room in use, we would predict that the room's smaller size would encourage the use of a lower voice level than in the larger conference room. Voice levels are still greater than those typically used in a private office, however. Moreover, the room's lack of absorptive materials and use of standard ceiling height wall construction contribute to a level of acoustical impact even greater than in the larger conference room, where a louder voice would typically be in use. An occupant in an adjacent office confirmed this behavior: "[I] can hear conversations from adjacent offices and from the conference room behind me. The conference room is worse."

Plan:
Case Study 8



Case Study 8

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level	Raised	66	Raised ¹³	66
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room	150 sq. ft.	6	150 sq. ft.	6
Sum Source Factors		87		87

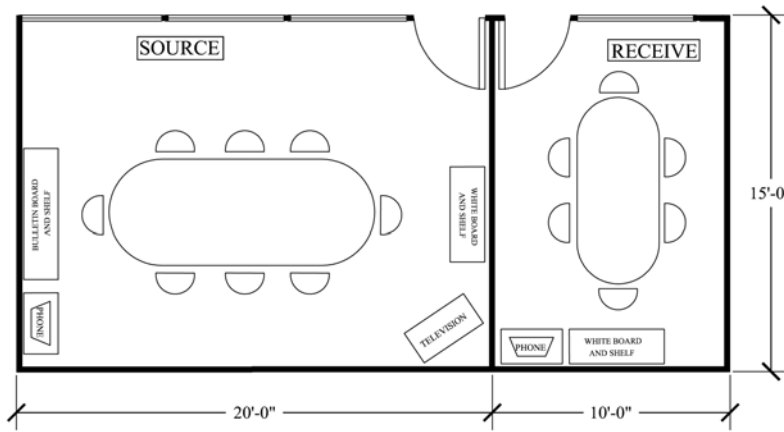
ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition: STC or NIC	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	Measured 3 1/2" steel stud 5/8" drywall each side	39
E. Effect of Receive Room (from table)		2		NA
F. Background Noise (dBA, receiving room)	Typical: Private Office	35	Measured	37
Sum Isolation Factors		76		76

SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+11		+11
Predicted level of acceptability		Strong dissatisfaction		Strong dissatisfaction

¹³ No conference was taking place, this value was predicted.

5.3 Case Study 9: Small to Large Conference Room

In this case study, we investigated the level of privacy between a small conference room and the adjacent large conference room. Although we did not observe either conference room in use, we used the same prediction of a raised (but not loud) source voice level used in Case Study 8. As was the situation in Case Study 8, the lack of absorptive material contribute to a level of acoustical impact on the larger conference room that would, as designed and tested, likely lead to significant complaints.



Plan:
Case Study 9

The following narrative comments in the CBE survey offer additional insight into this finding:

Meetings in adjoining conference rooms can sometimes generate enough noise to make concentration difficult.

Noise bleeds through all of the meeting rooms.

Case Study 9

SOURCE FACTORS	PREDICTED		OBSERVED	
A. Voice Source Level	Raised	66	Raised ¹⁴	66
B. Speech Privacy Criterion	Confidential	15	Confidential	15
C. Effect of Source Room	150 sq. ft.	6	150 sq. ft.	6
Sum Source Factors		87		87

ISOLATION FACTORS	PREDICTED		OBSERVED	
D. Partition: STC or NIC	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39	3 5/8" steel stud 5/8" drywall each side, slab to ceiling	39
E. Effect of Receive Room (from table)		3		NA
F. Background Noise (dBA, receiving room)	Typ.: Conference Room	32	Measured	31
Sum Isolation Factors		74		70

SOUND EXCESS	PREDICTED		OBSERVED	
Source factors minus isolation factors		+13		+17
Predicted level of acceptability		Strong dissatisfaction		Extreme dissatisfaction

¹⁴ No conference was taking place, this value was predicted.

6.0 CONCLUSIONS

Believing in the benefit of an open and collaborative work environment, an ever-greater number of managers, professionals and executives are abandoning private offices and adopting open plan areas with specialized office spaces to accommodate the casual conversations, informal meetings and even speakerphone use that once occurred in private offices. The poor performance of these open plan environments in occupant satisfaction surveys appears to primarily result from their inability to provide the level of speech privacy employees feel necessary for them to concentrate and be productive. The high level of acoustical dissatisfaction identified in these surveys may also be working to negate some of the presumed good will and free exchange of ideas associated with open-plan spaces.¹⁵ At the same time, a litigious environment and emphasis on the protection of intellectual property mean that speech privacy is more important than ever before. Clearly, there is a need for a reliable tool enabling building design and management professionals to evaluate whether a given office design will provide a satisfactory level of acoustical satisfaction.

Based on the nine case studies described above, the SPP method appears to offer an effective framework for anticipating speech privacy problems and crafting solutions for proposed spaces. In each case study, the level of acceptability for speech privacy predicted by the method was broadly congruent with the level of acoustic dissatisfaction reported by occupants of these spaces during our in-person interviews and with the aggregated response of occupants in case studies recorded by the CBE's post-occupancy evaluation survey.

Use of the SPP method during the design process also promise significant cost benefits, because acoustical upgrades are inexpensive when incorporated into the original design, but are substantially more expensive when performed as part of an acoustical retrofit. At the design stage, for example, the wall separating the private offices we studied could have been upgraded to provide an acceptable level of speech privacy simply by adding a 3-inch glass fiber blanket (\$0.60 per square foot), a layer of gypsum board (\$1.20 per square foot), and selecting a ceiling with a higher transmission loss rating (\$1.00 per square foot). Retrofitting these offices now, however, would involve completely rebuilding the wall (\$15 per square foot), as well as replacing the ceiling (\$3.50 per square foot), nearly ten-times the cost of the original upgrade. (See appendix 2.)

When used in open plan areas, the SPP method showed greater variability in its predicted results. Research is underway to establish the range of this variability, and to compare results obtained with the SPP method to those obtained with ASTM's widely accepted standard method for evaluating (but not predicting) speech privacy in open plan offices.¹⁶ An important next step in disseminating the SPP method will be to develop a companion design guide of best practices in acoustically successful office design, which will augment the SPP method's application among designers.

¹⁵ An extensive discussion of this phenomenon is offered in Brill (2001).

¹⁶ ASTM Method E 1130-90 (1994)

APPENDIX I DETAILED METHOD FOR USING THE SPEECH PRIVACY PREDICTOR (SPP)

Introduction

The Speech Privacy Predictor (SPP) is based on research by Cavanaugh, Farrell, Hirtle and Watters (Cavanaugh 1962). Cavanaugh found that the *ratio* of intruding speech to the ambient background noise in the office was the best predictor of satisfaction with speech privacy¹⁷. Cavanaugh's rating scheme considers five variables needed to determine the signal-to-noise ratio for a pair of adjacent office spaces. These variables are (1) how loud the voices of people using a space typically are, (2) the level of privacy required in the adjacent room, (3) the background noise occurring in the adjacent room (4) the effect of the size, furnishings and finishes of the adjoining rooms in absorbing sound and (5) the ability of the intervening partition to block sound. Cavanaugh's calculation procedure combines these variables into a single number rating for *sound excess*¹⁸. Cavanaugh has demonstrated a good statistical fit between the ratings of sound excess and levels of reported satisfaction.

Over the past 40 years, Cavanaugh's method of predicting an occupant's acoustic satisfaction based on the ratio of intruding speech to the ambient background noise has proved exceptionally durable. The Cavanaugh method underlies all leading approaches to quantifying office acoustics in North America, including those established by the American Society for Testing and Materials (ASTM, 1994) and the U.S. General Services Administration (GSA, 1975). As modified by Robert W. Young (1965), who simplified the measurement protocol, and by Rein Pirn (1971), who adapted the method for use in open plan offices, the Cavanaugh method forms the basis for the recommended method of evaluating office acoustics in three leading texts on acoustical design Egan (1988), Salter et.al. (1998) and Cavanaugh (1999). SPP draws upon the calculation procedure published in Egan (1988), Salter et.al. (1998) and Cavanaugh (1999).

Calculation Procedure

The SPP method calculates sound excess to predict the level of speech privacy acceptability of an office space. Drawing on simple design and space programming data, values representing 'source' and 'isolation' factors are each summed. Isolation factors are then subtracted from the source factors. Each of these variables are described in detail below, and the calculation procedure summarized in the worksheets shown in Figures A1 and A2. Note that the *source space* is the location where the occupant is speaking, and where the confidentiality of conversation will be evaluated. The *receive space* conversely is the location where the speech in the source space is intruding and can potentially be

¹⁷ This phenomenon is familiar to anyone who has dined in a crowded, noisy restaurant. Although the people at the adjacent table may be engaged in animated conversation less than four feet away, it is common not to be able to understand a word that they are saying. In fact, a space crowded with people talking is a very private environment, because even when using a raised voice, only the closest, most attentive listener can understand the speaker's words over the background 'din' of conversation.

¹⁸ The authors based their work on the 'Articulation Index' (French and Steinberg 1947; American National Standards Institute 1969) The Articulation Index relates physical measures of sound to predicted levels of speech intelligibility. Intelligibility refers to the degree to which speech can be clearly understood, and that words and sentences can be correctly identified.

overheard or will be distracting. Note also that the calculation procedure is somewhat different for open plan and enclosed office spaces.

Calculation of Source Factors

Source factors include two variables that are shaped by occupant behavior and expectations: *speech privacy criteria* and *source voice level*. In certain cases, overheard conversations may aid team processes. In others, the ability to understand even partial sentences may inhibit the ability to discuss sensitive work and personnel issues.

I. VOICE SOURCE LEVEL

Based on programming data, estimate the typical voice level associated with the loudest likely behavior of employees in the workgroup occupying the space. Typical voice levels are summarized in Table 1.

VOICE SOURCE LEVEL	TYPICAL ACTIVITY	CRITERIA (dBA)
Low	Telephone conversation using a low voice level	54
Conversational	Casual conversation between two people in an office setting	60
Raised	Conversation of three or more people in a meeting	66
Loud	Talking into a speakerphone, delivering a presentation	72

Table 1: Source Voice Levels

2. SPEECH PRIVACY CRITERIA

Acoustical engineers refer to three standard levels of speech privacy, which are summarized in Table 2. Based on programming data, determine which level of privacy is appropriate for the workgroup occupying the space.

LEVEL OF SPEECH PRIVACY	DESCRIPTION	CRITERIA (dBA)
Confidential	Speech from adjacent space is audible but not intelligible—the listener is aware that a conversation is occurring, but is not able to understand individual words	15
Normal	Speech from adjacent space is audible and partially intelligible—the listener has the ability to comprehend an occasional word but never full sentences	9
Marginal	Speech from adjacent space is largely understandable	3

Table 2: Speech Privacy Criteria

3. EFFECT OF SOURCE ROOM

In private offices and conference spaces, voice levels in the source room are adjusted to account for the amount of absorption provided by the furnishings and room volume. These values are listed in Table 3.

Table 3:
Adjustment for
Source Room
Effect
(Private Offices
and Conference
Rooms)

FLOOR AREA (SQURE FEET)	CRITERIA ROOM WITH 50% ABSORPTIVE SURFACES (dBA)¹⁹	CRITERIA ROOM WITH LESS THAN 20% ABSORPTIVE SURFACES (dBA)
60	+9	+15
125	+6	+12
250	+3	+9
500	0	+6
1000	-3	+3

Calculation of Isolation Factors

4. DISTANCE FROM SOURCE (OPEN PLAN AREAS)

Sound from the source workstation will attenuate as the distance between workstations increases. Table 4 provides values for this effect. Note that these values assume absorptive ceiling and workstation partitions and carpeted floors.

Table 4:
Absorption (Open
Plan Offices)

DISTANCE FROM SOURCE WORKSTATION TO RECEIVER WORKSTATION (FEET)	CRITERIA (dBA)
3	0
6	5
12	10
24	15

5. BARRIER NOISE REDUCTION (OPEN PLAN AREAS)

This criterion accounts for the effectiveness of the partitions between workstations in both blocking sound. Because the partitions in an open plan do not extend to the ceiling, the noise reduction they provide is a function of STC of the partition itself, the layout of the workstations and the amount of absorptive finishes in the space. To calculate the effectiveness of partitions in an open plan, refer to Figure A2 and Table 5. Note that this calculation assumes an absorptive ceiling (minimum NRC of .65), partition components with a minimum STC of 18, and 50% of panels/wall surfaces above 3 feet having sound absorbing materials, such as bookcases with books or acoustical panels. Note also that partition heights in excess of 68 inches provide additional little sound reduction unless they continue to an acoustically sealed connection at the underside of the ceiling.

¹⁹ Absorptive surfaces include absorptive wall and ceiling materials, upholstered furniture, bookcases with books, and carpeting. Hard surfaces include gypsum board walls and/or ceilings, vinyl or concrete floors, upholstered furniture, bare desks.

DISTANCE: RECEIVER TO BARRIER	CRITERIA: BARRIER HEIGHT/DISTANCE SOURCE TO BARRIER											
	SLIGHT BREAK IN LINE OF SIGHT DISTANCE: SOURCE TO BARRIER			1-FOOT BREAK IN LINE OF SIGHT DISTANCE: SOURCE TO BARRIER			2-FOOT BREAK IN LINE OF SIGHT DISTANCE: SOURCE TO BARRIER			3 FOOT BREAK IN LINE OF SIGHT DISTANCE: SOURCE TO BARRIER		
	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.	3 ft.	6 ft.	12 ft.
3-feet	5	5	5	8	7	7	11	10	9	13	12	12
6-feet	5	5	5	7	7	6	10	9	8	12	11	10
12-feet	5	5	5	7	6	6	9	8	8	12	10	9

Table 5: Barrier Noise Reduction (Open Plan)

6. PARTITION CONSTRUCTION (PRIVATE OFFICES AND CONFERENCE ROOMS)

This criterion accounts for the acoustic performance of the walls separating the source and receive spaces. This value is measured in terms of the Sound Transmission Class (STC) rating of the partition.²⁰ Table 6 lists STC values for standard partition types. Note that these values assume full height (slab to slab) construction, and the use of acoustical sealant at all penetrations and wall connections. Wall performance will be less if there are even small gaps at floor/ceiling connections, corners, doors frames, outlet boxes, or if the wall terminates at the underside of an un-insulated suspended ceiling.

WALL TYPE	CRITERIA (STC)
3 5/8" metal studs, 24" o.c., 1 layer 5/8" gypsum board each side	39
Same as above, with 3" glass fiber in cavity	44
Same as above, with 3" glass fiber in cavity and 2 layers 5/8" gypsum board one side	50
Double row of 3 5/8" metal studs on separate plates, 24" o.c., 1 inch between plates, 1 layer 5/8" gypsum board each side, 3 1/2" glass fiber both sides	59
Same as above, 2 layers 5/8" gypsum board each side	63

Table 6: STC Values of Typical Wall Types

²⁰ Transmission loss is typically measured in 16 one-third-octave bands and can be expressed through a single-number rating scheme called Sound Transmission Class or STC. Higher STC values represent better noise reduction

7. EFFECT OF RECEIVE ROOM (PRIVATE OFFICES AND CONFERENCE ROOMS)

The receive room will absorb some of the intruding sound radiating from the common wall. Table 7 shows the values accounting for this effect.

Table 7:
Absorption in
Receive Room
(Private Offices
and Conference
Rooms)

RATIO FLOOR AREA RECEIVE ROOM COMMON PARTITION AREA	CRITERIA ROOM WITH 50% ABSORPTIVE SURFACES (dBA) ²¹	CRITERIA ROOM WITH LESS THAN 20% ABSORPTIVE SURFACES (dBA)
1	+0	-5
1.5	+2	-3
2	+3	-2
3	+5	0
4	+6	+1
5	+7	+2
6	+8	+3
10	+10	+5

8. BACKGROUND NOISE LEVEL

The level of background noise in the receive space is critical in masking speech from the adjoining source space. Based on research summarized by Egan (1998), if intruding speech is on average 10 dB below the background noise, satisfaction with speech privacy approaches 100%. Conversely, if intruding speech is on average 5 dB above background noise, dissatisfaction approaches 100%.

Although it may seem counter-intuitive, many contemporary open plan office spaces are too quiet, and require the insertion of additional noise. This noise is called ‘sound masking’ and represents a ‘controlled quiet’ that sounds somewhat like ventilation noise. Sound masking differs from ‘pink’ noise (unpleasant, unnatural) and ‘white’ noise (hissy, annoying). Sound masking needs to be specified and installed by a trained professional, because it is specifically tuned in a given space to offer an optimum sound spectrum.

Table 8: Typical
Background Noise
Levels

CONDITION	CRITERIA (BACKGROUND SOUND, dBA)
Quiet ventilation system, no nearby office equipment, no traffic noise intrusion through building façade, sound absorbing ceiling	30
Recommended limit for steady state background noise in private offices and conference rooms	35
Constant air volume mechanical system, nearby office equipment and/or moderate traffic intrusion, standard acoustical tile ceiling	40
Sound masking system	45
Recommended limit for steady state background noise in open plan areas	50

²¹ Absorptive surfaces include absorptive wall and ceiling materials, upholstered furniture, bookcases with books, and carpeting. Hard surfaces include gypsum board walls and/or ceilings, vinyl or concrete floors, unupholstered furniture, bare desks.

FIGURE A1: SPEECH PRIVACY ANALYSIS PROCEDURE FOR OPEN PLAN OFFICES

Adapted from Cavanaugh (1962), Young (1965), Pirn (1971) and Egan (1972).

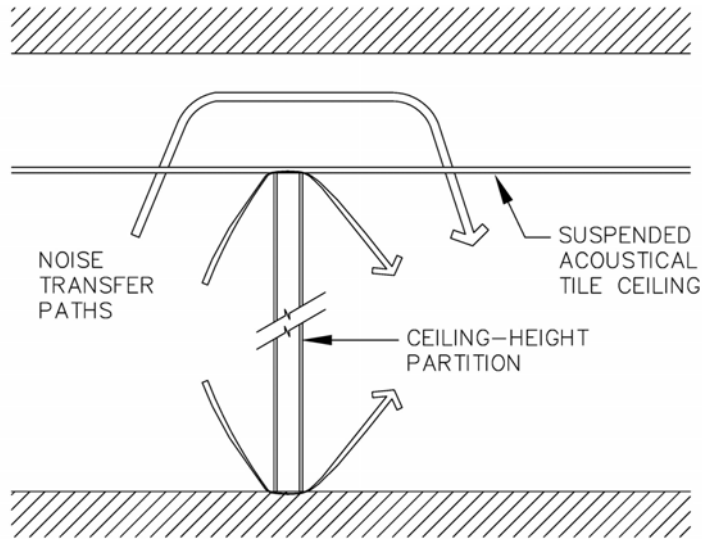
SOURCE FACTORS		
A. Voice Source Level	Value from Table 1	A
B. Speech Privacy Criterion	Value from Table 2	B
Sum Source Factors		A+B
ISOLATION FACTORS		
C. Distance from Source	Value from Table 4	C
D. Barrier Noise Reduction	Value from Table 5	D
E. Background Noise	Value from Table 8	E
Sum Isolation Factors		C+D+E
SOUND EXCESS		
Sum Source Factors – Sum Isolation Factors		(A+B) – (C+D+E)
Predicted Level of Acceptability	Value from Figure 2, pg. 6	

FIGURE A2: SPEECH PRIVACY WORKSHEET FOR ENCLOSED OFFICES

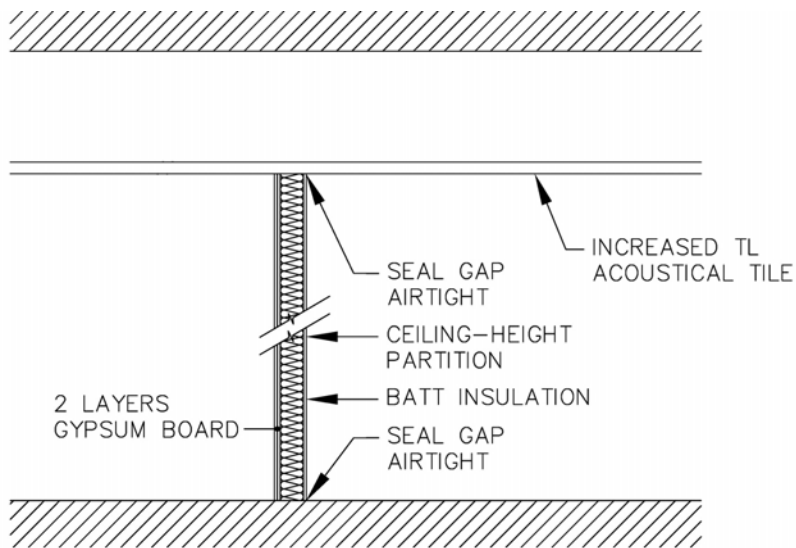
Adapted from Cavanaugh (1962), Young (1965), and Egan (1972).

SOURCE FACTORS		
A. Voice Source Level	Value from Table 1	A
B. Speech Privacy Criterion	Value from Table 2	B
C. Effect of Source Room	Value from Table 3	C
Sum Source Factors		A+B+C
ISOLATION FACTORS		
D. Partition STC or NIC	Value from Table 6	C
E. Effect of Receive Room	Table from Table 7	E
F. Background Noise (Receive Room)	Value from Table 8	F
Sum Isolation Factors		D+E+F
SOUND EXCESS		
Sum Source Factors minus Sum Isolation Factors		(A+B+C) – (D+E+F)
Predicted Level of Acceptability	Value from Figure 2, pg. 6	

APPENDIX 2: CONSTRUCTION DETAILS FOR ACOUSTICAL PRIVACY



Typical “as built”
partition for
private offices



Recommended
acoustical design
for private
offices with
'normal' speech
privacy

APPENDIX 3: SURVEY METHODS AND RESULTS

This report presents the results from a Post Occupancy Evaluation of a high rise commercial office building in San Francisco, CA. The assessment took place in the form of a web-based survey that was administered between November 27, 2000 and December 5th, 2000. Participation in the survey was voluntary and anonymous. Responses were collected via the Internet and recorded to a database hosted at a third party vendor. The project was sponsored jointly by CBE and the building's owner.

Employees received an e-mail inviting them to take the survey. An additional 51 employees without an e-mail address were sent a hard copy letter inviting them to take the survey at a series of computers at the set up for that purpose. Respondents were advised that the purpose of the survey was to elicit quantitative information on how successful their building was in meeting its design goals, and that this information would be used by the building's owners, managers, consultant team, maintenance personnel and CBE research staff to develop scenarios for an improved building.

A total of 687 employees logged on to the survey, an overall response rate of 47%. The resulting report contained only aggregated, anonymous results. Any information disclosing what an individual employee said has been removed.

The survey covered twelve general areas of the work environment in a commercial office building. Respondents were asked to evaluate their "satisfaction" with aspects of these general areas. The survey employed a mix of yes/no questions and 7-point satisfaction scales that range from "very satisfied" to "very dissatisfied". In most cases, respondents who indicated "dissatisfaction" (the lowest two points on the scale) with a particular aspect were branched to a follow up screen probing them for more information about the nature of their dissatisfaction. Respondents who indicated higher satisfaction moved directly to the next survey topic. Where applicable, respondents were also asked to assess the impact of these general areas of the work environment on their effectiveness in getting their job done.

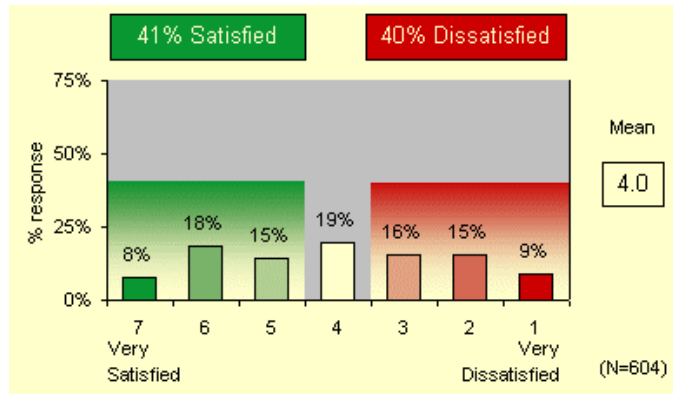
Screen capture from
on-line survey



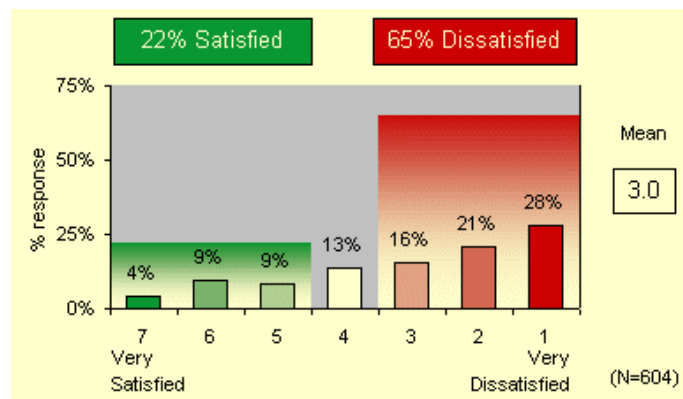
In order to analyze the data, responses to each satisfaction question have been counted in three bins: "Dissatisfied", the bottom three points on the 7-point scale; "Neutral", the middle point on the scale; and "Satisfied" the top three points on the standard scale. Importance questions have been evaluated in a similar way with three bins: "Low Importance", "Neutral", and "High Importance". For each question the data are displayed as the percentage of total respondents who responded to the question in each of the three bins. In this way the responses to various questions can be ranked and compared against one another. Each page of the survey also included space for respondents to make comments, including a "general comments" section at the end of the survey.

Results for Acoustics Questions

Selected survey results are illustrated in the table below.



Survey Question:
How satisfied are you with the noise level in your office? (noise generated by things other than your own work)



Survey Question:
How satisfied are you with your sound privacy? (ability to have conversations without your neighbors overhearing and vice versa)?

Building Systems

The building's mechanical system is typical of the majority of Class-A office space constructed during the past 30 years. Structurally, the building has a steel frame with metal deck/lightweight concrete floors. Perimeter glazing is fixed. HVAC is a variable air volume (VAV) system supplied from diffusers surrounding light fixtures. Return air is ducted. Ceilings are 2' x 2' acoustical tile suspended 2-6" below the floor deck above. 2 x 4 ceiling fixtures with specular parabolic lenses supply direct overhead lighting. Most open plan areas are laid out adjacent to the perimeter, with private offices, conference rooms, circulation and service spaces in the core. Windows have horizontal blinds.

APPENDIX 4: TESTING PROTOCOL

Measurements were conducted on the Monday, February 12 and Tuesday February 13, 2001. The facility manager characterized occupancy as typical; we observed approximately 80% of workstations and private offices occupied.

In each case study location, occupant behavior was observed to note the location and levels of typical speech activity. A scale drawing of the workstation, office or conference room layout was then made, recording the typical locations of occupants in the source and evaluation spaces and the position of office screens, desks, doors, glazing, telephones, computers, chairs and other acoustically relevant furnishings and finishes. The height and acoustical attributes of the office screens and the ceiling were identified, along with a description of the floor, overhead lighting and ventilation. Digital photographs documented the juxtaposition of workstations and the adjoining environment. When possible, with full understanding of the confidentiality of their response, occupants were interviewed about their expectations for and satisfaction with their speech privacy.

Field measurement of background noise and transmission loss of partitions was then performed. Using a calibrated tape recording system, the typical background noise level was measured at each receiver location. Background sound level was defined in terms of the minimum A-weighted background sound pressure level (L_{min}). L_{min} represents the lowest background level, independent of single-event sounds such as telephone ringing, that can unintentionally inflate a predicted level of the effectiveness of background noise. The microphone during the recording was slowly moved in an approximately 1-foot-diameter circle about 4 feet above the floor. Measurements included a time period of approximately 4 seconds at each of four positions set at 90 degree intervals in the circle.

In open plan areas, noise reduction from the source to the receiver location was measured as follows. A calibrated loudspeaker generating pink noise was located at height and location observed as most typical of the person(s) talking at the source location. The sound level of the loudspeaker was then measured three feet in front of it and at location observed as most typical of the person(s) sitting at the receive location. The sound level of the loudspeaker was at least 10 dB more than the ambient at the receiver location. Measurements were made following the same procedure as described for the ambient measurement.

In private offices and conference rooms, noise reduction was measured as follows: 1-minute space average sound level measurements were conducted in the source and then in the receive room. In the receive room, the reverberation time was measured at five locations.

Acoustical instrumentation used to conduct these tests consisted of the following: the sound source was an ADS 2002 loudspeaker meeting the frequency response and sound level variation requirements set forth in ASTM E1179 for acoustical testing in open-plan offices. Measurements were recorded with a 1/2-inch diameter condenser microphone fitted to a B&K 2230 sound level meter outputting a calibrated signal to a Sony TC-D5M cassette recorder.

REFERENCES

- American National Standards Institute (1969). "American National Standard S3.5-1969: Methods for the Calculation of the Articulation Index", New York: American National Standards Institute
- ASTM (1994). Method E 1130-90. . "Standard Test Method for Objective Measurement of Speech Privacy in Open Offices Using Articulation Index", *Annual Book of ASTM Standards 2001 Volume 4.06*
- Boggs, D.H. , and J.R. Simon (1968). "Differential effect of noise on tasks of varying complexity". *Journal of Applied Psychology* 52:148-153.
- Brill, M., S. Margulis, et al. (1984). *Using Office Design to Increase Productivity*. Buffalo, N.Y.: Workplace Design & Productivity.
- Brill, M., S. Weidemann and the BOSTI Associates (2001). *Disproving Widespread Myths About Workplace Design*. Kimball International, Jasper, IN
- Cavanaugh, W.J., W.R. Farrell, P.W. Hirtle, and B.G. Watters, Bolt Beranek & Newman (1962). "Speech Privacy in Buildings," *Journal of the Acoustical Society of America*, vol. 34, pp. 475-492
- Cavanaugh, W. J. and J. A. Wilkes (1999). *Architectural Acoustics. Principles and Practice*. New York, NY, Wiley.
- Center for the Built Environment/Skidmore Owings and Merrill, (2001). "Post Occupancy Evaluation Survey". (web only resource). Berkeley, California: University of California.
- DeMarco T., and T. Lister (1987) *Peopeware: Productive Projects and Teams*. New York: Dorset House Publishing.
- Egan, M. D. (1972). *Concepts in Architectural Acoustics*. New York, NY, McGraw Hill.
- Egan, M. D. (1988). *Architectural Acoustics*. New York, NY, McGraw Hill.
- Evans, G. W. and D. Johnson (2000). Stress and Open-Office Noise. *Journal of Applied Psychology*, Vol. 85, No. 5, 779-783
- French, N. R. and J. C. Steinberg (1947). "Factors governing the intelligibility of speech sounds." *Journal of the Acoustical Society of America* 19(1): 90-119.
- Harris, L. (1978). *The Steelcase National Study of Office Environments: Do They Work?* Grand Rapids, MI , Steelcase, Inc.
- Harris, L. (1991). *The Office Environment Index 1991: Summary of Worldwide Findings*. New York: Louis Harris and Associates
- Junqua, J.-C. (1993). "The Lombard reflex and its role on human listeners and automatic speech recognizers." *J. Acou. Soc. America* 93(1): 510-524.
- Karacek, R., and T. Theorell. (1990). *Healthy Work: Stress, Productivity and the Reconstruction of Working Life*. New York: Basic Books.
- Lombard, E. (1911) "Le signe de l'elevation de la voix.." *Ann. Maladies Oreille Larynx* 37, 101--119
- Pirn, Rein. (1971). Acoustical Variables in Open Planning," *Journal of the Acoustical Society of America* vol. 49 (5), part 1, pp. 1339-1345
- Salter, C. M. et. al. (1998). *Acoustics. Architecture, Engineering, The Environment*. San Francisco, William Stout Publishers

Sundstrom, E., J.P. Town, R.W. Rice, D.P. Osborn and M. Brill (1994). "Office noise, satisfaction, and performance". *Environment and Behavior* 26(2): 195-222.

U.S. General Services Administration/Geiger & Hamme. (1975). *Public Building Service Standard Method of Test Method for the Sufficient Verification of Speech Privacy Potential (SPP) Based on Objective Measurements*. Washington, D.C PBS (PCD): PBS-C.2

Young, Robert W (1965). "Re-Vision of the Speech-Privacy Calculation,". *Journal of the Acoustical Society of America*, vol. 38 (4), pp. 524-530