INT&RIOR SYSTEMS

Guiding Design • Informed Interiors

Acoustic Solutions

Education Acoustics

Updated to reflect MOE DQLS 2016 Version 2.0

Education Acoustics

Great Acoustics = Better Learning Outcomes

- New DQLS guidelines set out minimum design standards. New projects or upgrades need to comply with the standards.
- The critical relationship between good acoustics and good learning outcomes is becoming increasingly recognised in New Zealand and overseas.
- Providing suitable acoustics in a classroom is important in ensuring that acoustics do not adversely affect the learning capabilities of children.

This eBook:

Guidelines: Acoustic design parameters for classrooms

Acoustic Pitfalls: How they can be avoided.

Helpful Tips: D.I.Y. Acoustics

Solutions: New build and remedial work

See: www.tris.co.nz

Welcome

This eBook Series is brought to you by...

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She has performed throughout New Zealand, as well as in Tonga, China and England and has worked as an AV designer for numerous operas in New Zealand, England, Scotland and France.

With Thanks to Dr John Pearce from Canterbury University of Canterbury for his comments and review.

INT&RIOR SYSTEMS

creating quality ambient spaces

Education Acoustics

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Introduction

The American Speech-Language-Hearing Association (ASHA) published a Position Statement and Guidelines for Acoustics in Educational Settings in 1995. Within it, they recommend that in classrooms, Background Noise levels should not exceed 30 dBA, Reverberation Times must be 0.4 seconds or less, and there should be an overall teacher Signal-to-Noise Ratio of +15 dB.

These specifications were largely confirmed in 2002 when the American National Standards Institute (ANSI) published *ANSI S12.60-2002 Acoustical Performance Criteria, Design Requirements and Guidelines for Schools (ANSI, 2002)*, that, based on room size, recommends that Background Noise level should not exceed 35 dBA, Reverberation Time not to exceed 0.6–0.7 seconds, and that the Signal-to-Noise Ratio should be +15 dB. The acoustical performance standards in ANSI S12.60-2002 are based on the results of studies on classroom acoustics and the resulting impact on speech communication.

For new or substantially renovated schools to be LEED® certified, unoccupied classroom Background Noise levels cannot exceed 45 dBA. Additionally, classrooms smaller than 20,000 cubic feet (570 cubic metres) require a total area of sound-absorbing finishes with a minimum NRC rating of 0.70 equal to the room's ceiling area, while classrooms larger than 20,000 cubic feet (570 cubic metres)) require a Reverberation Time of less than 1.5 seconds (U.S. Green Building Council, 2009).

- Oticon NZ's study of New Zealand Primary Schools highlighted that:
- 71% of teachers felt that internal classroom noise was a problem (Background Noise)
- More than one-third of the teachers indicated they had to speak at a level that strained their voices (Signal-to-Noise Ratio)
- Approximately half the teachers said they had to considerably raise their voices during group work. (Valentine, et al, 2002)

Guidelines from the Ministry of Education (NZ) state that improving any aspect of acoustics should not be considered in isolation from other environmental factors. Acoustics, ventilation, temperature, air quality and daylight are all inter-related and a change to any one could affect the others.

Background Noise is comprised of noise from building systems, exterior sound transmission, sound created within a room and sound from adjacent spaces. While a 1 decibel change in sound level is barely noticeable, Background Noises are perceived as doubling in loudness with every 10 dB increase. Excessive Background Noise can seriously degrade communication.

Good acoustics is something that designers, architects and acousticians can actively contribute.

Please Note: The dBA scale is an adapted dB scale -providing different weighting to the dB level at different frequencies. It approximates the human ear's response to sound. The A-weighted scale is less sensitive to very high and very low frequencies mimicking the behaviour of our ears. Other weightings sometimes used are the C and D scale (dBC, and dBD).

Background Noise

Reverberation Time

Specific criteria for acoutic-measurements in classrooms are currently not yet included in the New Zealand Building Code, and this responsibility falls with architects and designers. However, the New Zealand Ministry of Education encourages schools to ensure that coustic conditions in teaching spaces provide the best possible outcome and strongly recomend that schools remedy any acoustic shortcomings.

Guidelines from the Ministry of Education (NZ) state that improving an aspect of acoustics should not be considered in isolation from other environmental factors. Acoustic, ventilation, temperature, air quality and daylight are all inter-related and a change to one could affect the others.

New Build

"From the very outset of any building development, the selection of the site, the location of buildings on the site, and even the arrangement of spaces within the building can, and often do, influence the extent of the acoustical problems involved. The materials and construction elements that shape the finished spaces will also determine how sounds will be perceived in that space as well as how they will be transmitted to adjacent spaces."
William J. Cavanaugh and Joseph A. Wilkes, *Architectural Acoustics, Principles and Practice* (1999)

Good acoustics cannot be achieved by enhancing one single parameter. It's a set of factors that need to be aligned to the purpose of the room. For new construction, architects and designers must account for acoustics in the design phase. Doing so means taking the following factors into consideration:

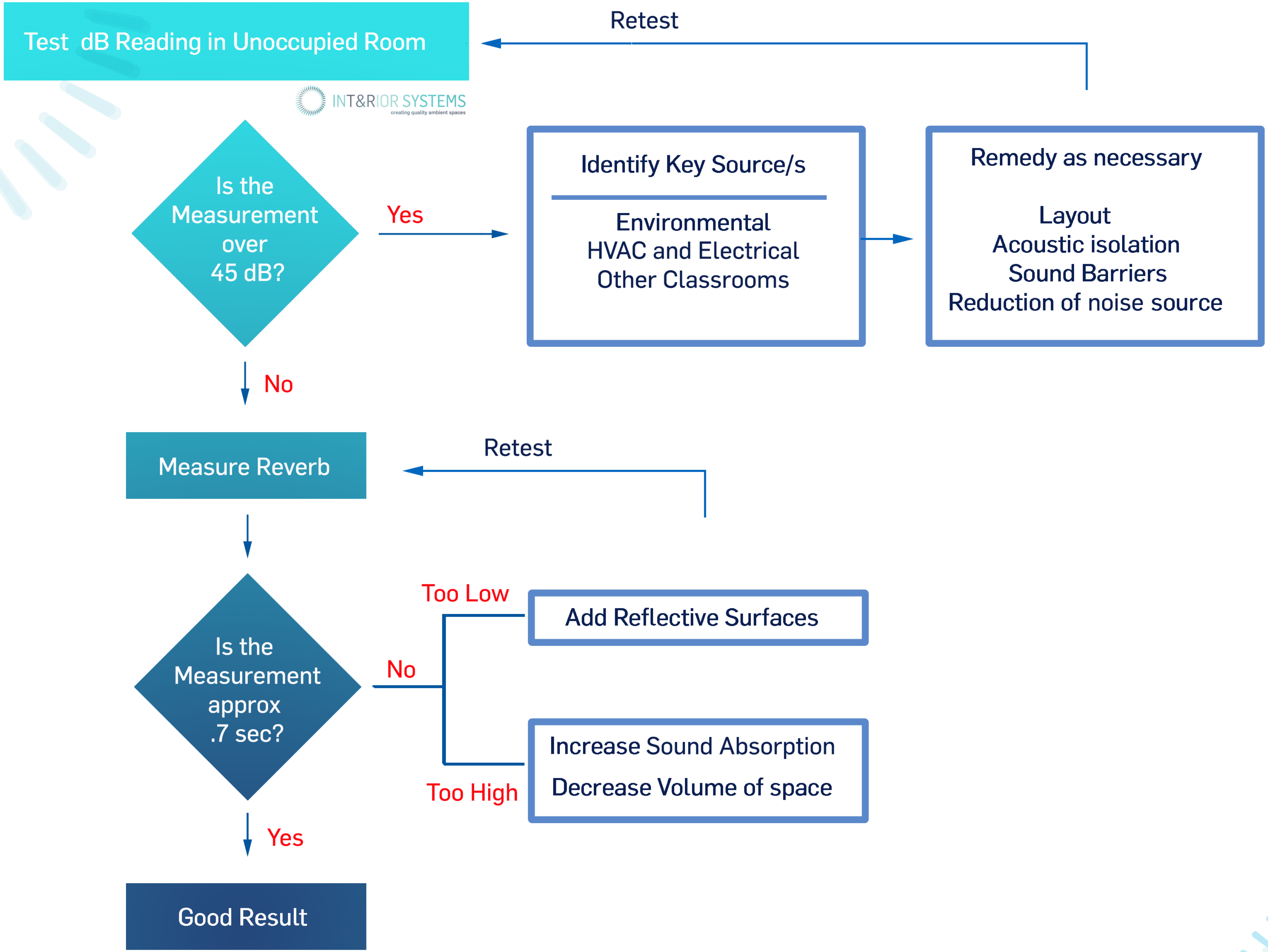
- Environmental Noise – weather, nearby roads, trains, weather and other transportation- or industry-related sources.
- HVAC or other equipment on the premises.
- Transmitted or attenuated noise from other classrooms or other areas of the facility
- Noise created within classrooms – expected activities, electrical equipment, furniture and HVAC

It always costs more to implement acoustic treatment after a building is completed than to install it during the initial construction.

Remedial Work

Evaluating the acoustic suitability of a classroom is the first important step in ensuring that unsatisfactory acoustics do not adversely affect learning. The Ministry of Education strongly recommends that designers or acoustics specialists carry out an acoustic assessment on site, and that any shortcomings highlighted by the assessment are remedied.

BRANZ recommends that before deciding to improve the acoustics of existing classrooms the age and general condition of the building should be considered. The work could be part of a comprehensive project that includes other essential upgrading work. When evaluating how serious the acoustic issues are and the options available to correct them, re-organisation of the spaces may be required.


Test dB Reading in Unoccupied Room
Retest
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Is the Measurement over 45 dB?
Yes
Identify Key Source/s
Environmental
HVAC and Electrical
Other Classrooms
Remedy as necessary
Layout
Acoustic isolation
Sound Barriers
Reduction of noise source
No
Measure Reverb
Retest
Is the Measurement approx .7 sec?
Too Low
Add Reflective Surfaces
No
Increase Sound Absorption
Decrease Volume of space
Too High
Yes
Good Result

ILE Design

New classrooms are being designed as open-plan environments where several class-bases share the same space, (resulting in a large number of children in one larger area). These Innovative Learning Environments (ILE) are emerging to facilitate group work and benefit the children's social development; promoting the sharing of skills, ideas and experiences. More open and connected learning spaces are more flexible and adaptable and provide greater opportunities for collaboration and a broader range of concurrent activities.

However, many acoustic issues arise with ILE, such as high noise levels coming from other class-bases in the same space. Acoustic conditions often do not facilitate a good Signal to Noise Ratio, especially further away from the teacher. Furthermore, the larger spatial volumes lead to higher reverberation times that negatively affect Speech Intelligibility. Longer reverberation times also exacerbate background noise.

An acoustic design that ensures adequate absorption of ambient and activity noise levels is crucial.

When designing a new learning space or extending an existing facility, designers are to consider several factors in order to meet the acoustic performance standards in DQLS version 2.0.

ILE Design

The main aims of ILE classrooms are:

Designing for flexibility

Internal noise – considerations for using sound absorbing materials

External noise – considerations for school layout planning at master plan stage

The designs of new learning spaces are to carefully balance flexibility and adaptability of use with the acoustic performance required for a range of learning activities. The design should aim to provide:

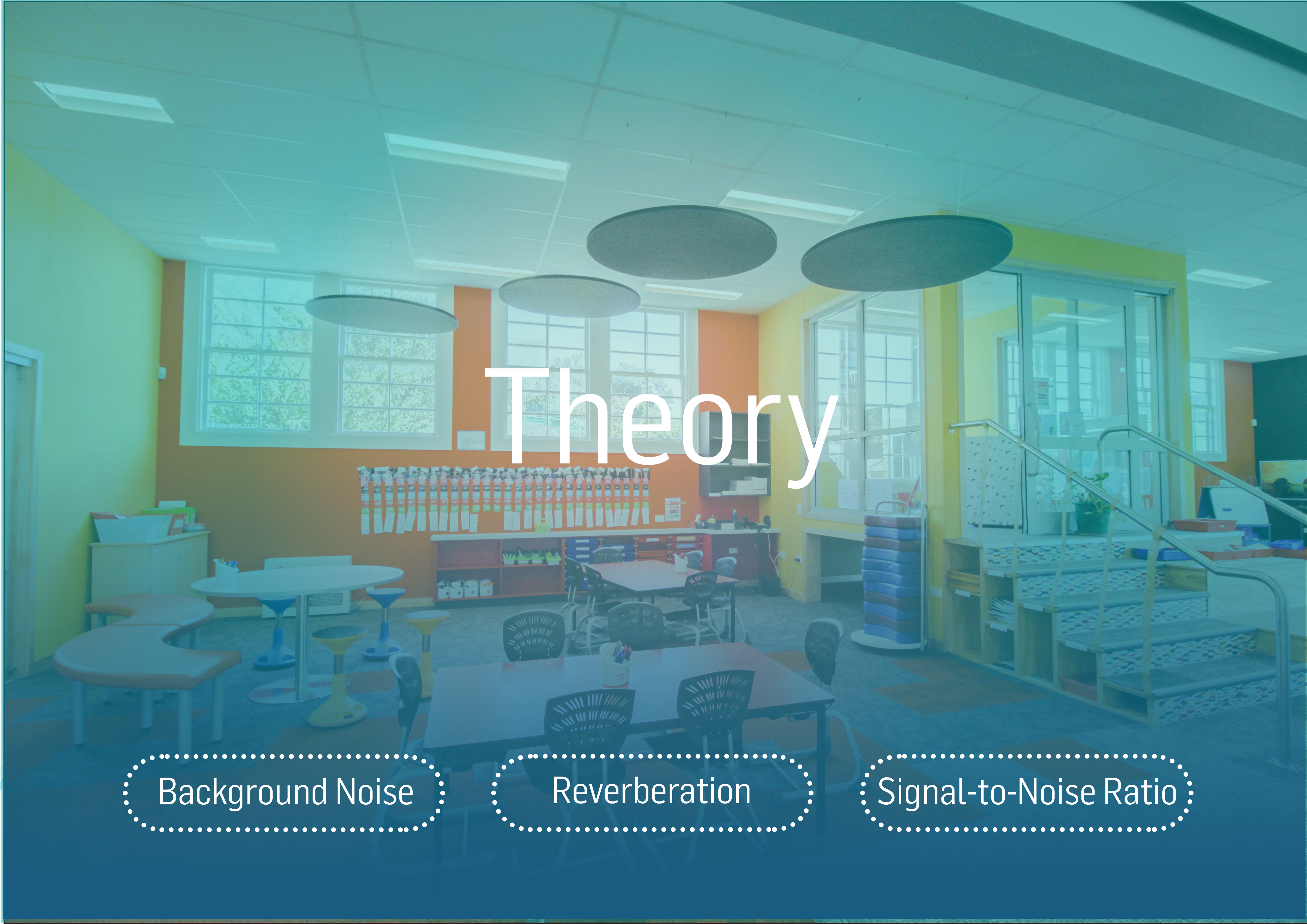
A range of spaces to allow teachers and students to choose where they learn,

Degrees of acoustic separation, which will help to reduce distraction from other activities.

Provision of break-out learning areas, with a level of acoustic separation while maintaining flexibility and connectivity should be incorporated in to a flexible learning space.

A flexible design not only provides a more flexible learning space, it provides excellent scope to achieve good acoustic performance. MOE DQLS version 2.0

A teacher's perspective of Acoustics in New Zealand Classrooms



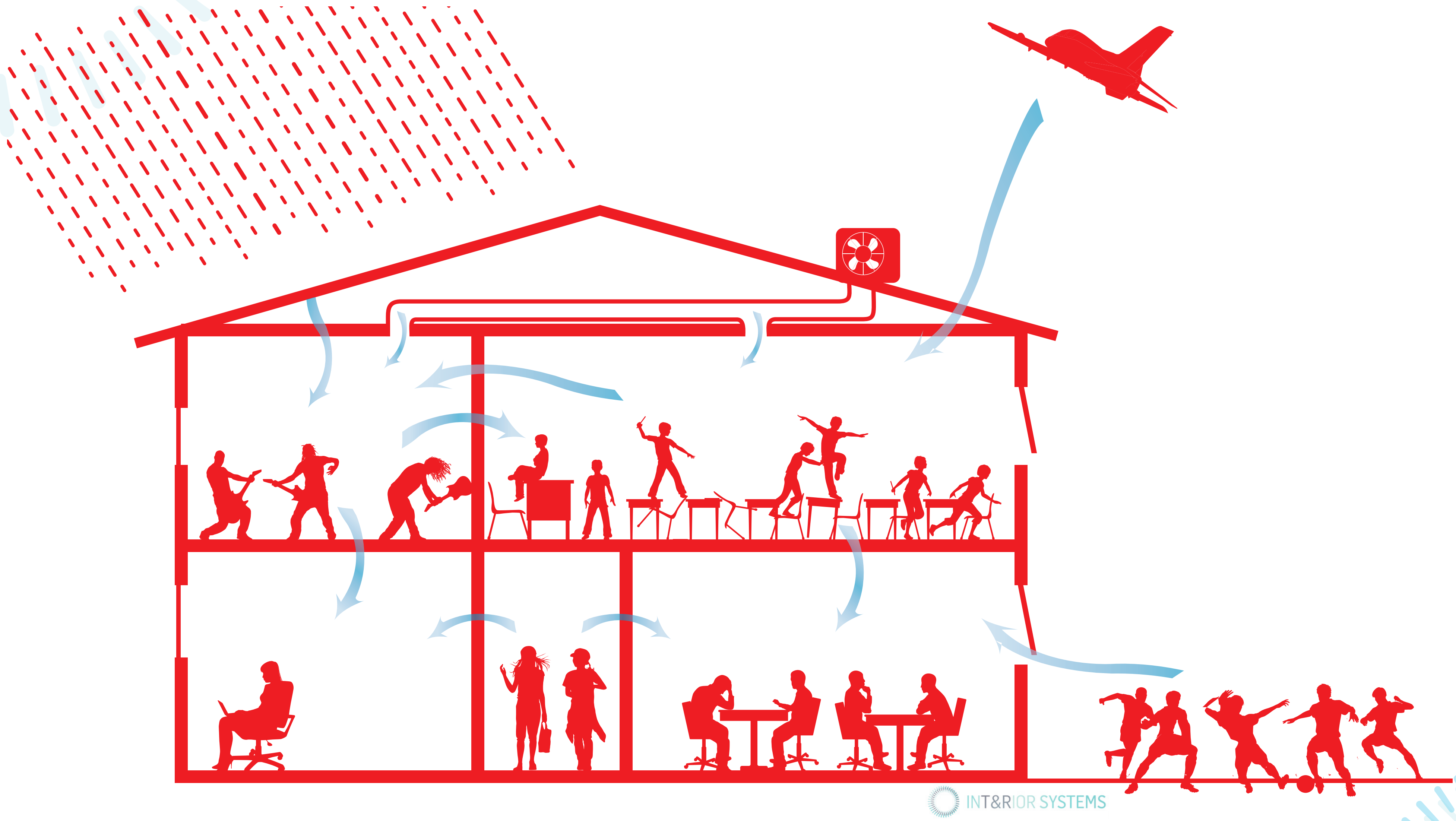
Theory

Background Noise

Reverberation

Signal-to-Noise Ratio

Background Noise



Background Noise is comprised of noise from building systems, exterior sound transmission, sound created within a room and sound from adjacent spaces. While a 1 decibel change in sound level is barely noticeable, Background Noises are perceived as doubling in loudness with every 10 dB increase. Excessive Background Noise can seriously degrade communication.

Many sources contribute to the Background Noise level of a classroom, including:

• Environmental noise generated outside the school property (road traffic and building construction) and noise generated within the school property (grass cutting, the playground and playing fields)

• HVAC systems

• Sound transferred and attenuated from nearby classrooms, corridors and noisy areas (music and technologyrooms)

• Noise created within the classroom, talking and other activities as well as moving furniture, paper rustling, computers and fans etc. when the room is occupied.

Teachers have indicated that the greatest noise source in the classroom is attributed to lawn mowing, their sports fields and other classrooms. (BRANZ, 2007) Because most windows provide ventilation for the classroom, exterior environmental noise, which often contributes to high classroom noise, can be difficult to control. Improving acoustics to help minimise outside noise cannot be seen in isolation from the impact on other important aspects such as ventilation and air quality.

dB Scale

96 dB: Maximum level for public events in some countries

85 dB: EU, maximum exposure level

80 dB: Police or fire siren, electric shaver

75 dB: Noisy restaurant

70 dB: Loud conversation

65 dB: Reception areas / noisy office room

60 dB: Normal conversation / walking on hard floors

55 dB: Average office / telephone, copier

50 dB: Printer / ventilation noise (high)

45 dB: Typing

40 dB: Quiet office room

35 dB: Ventilation noise (low)

30 dB: Whisper

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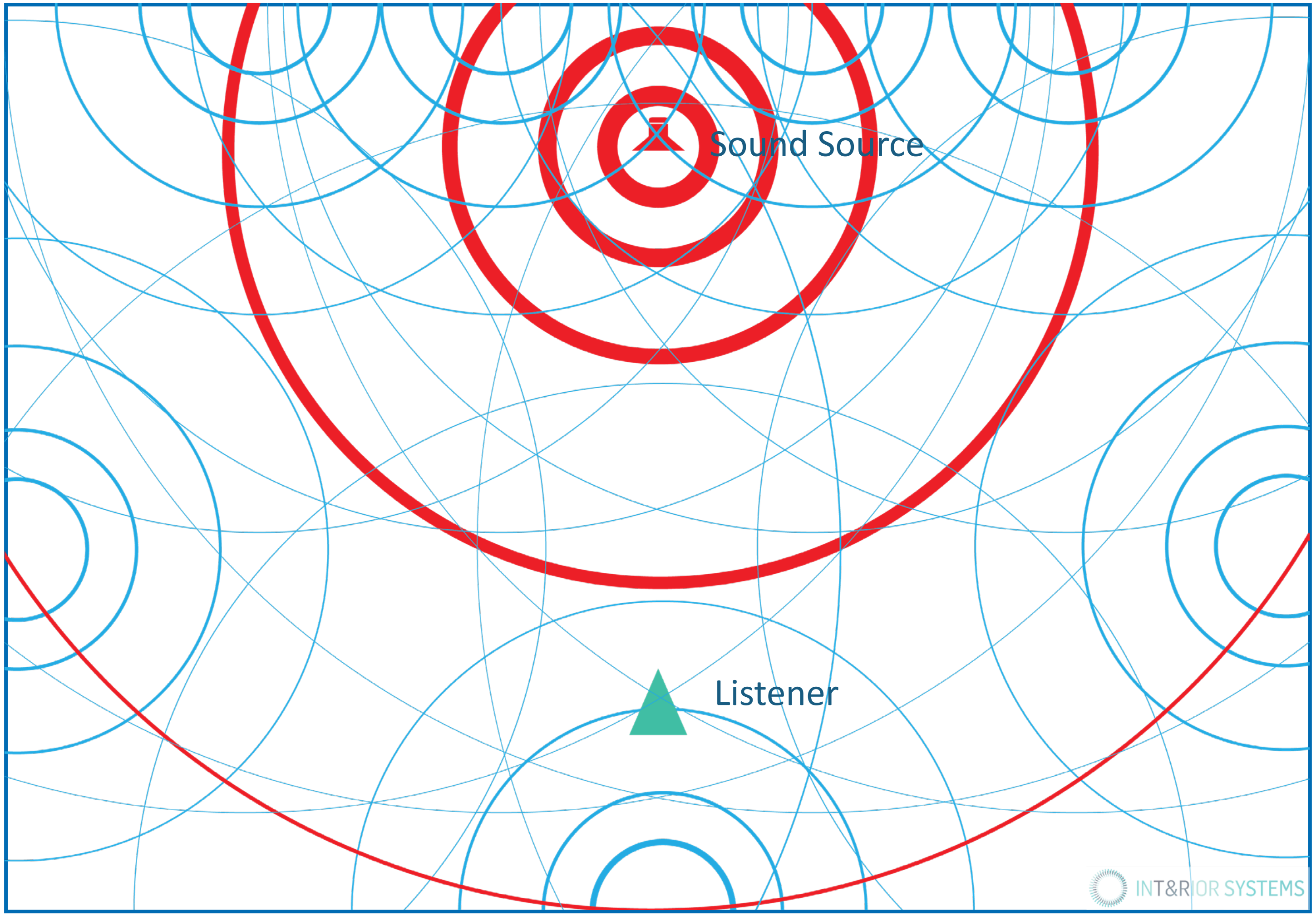
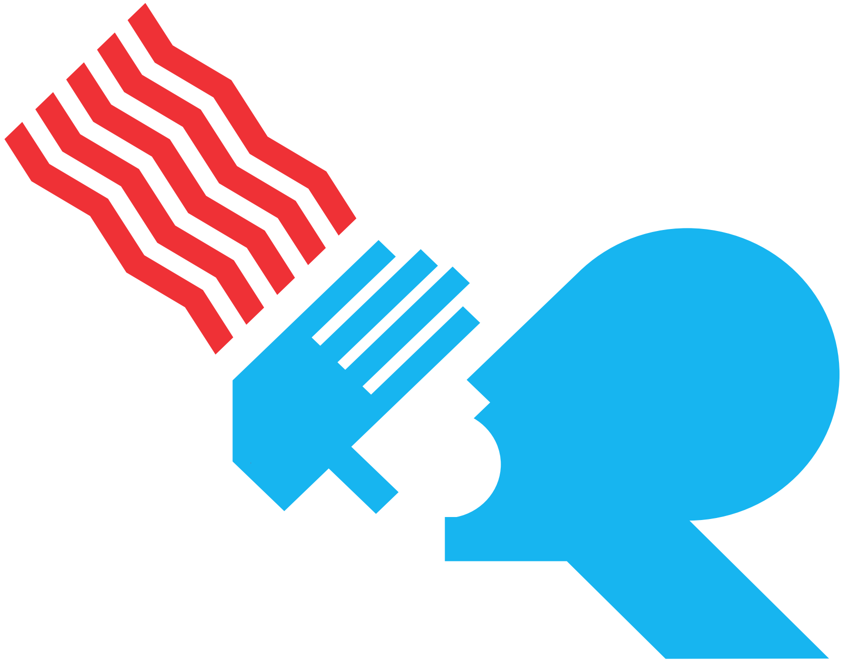
Reverberation



Although some reverberation within a space can aide in speech distribution, longer Reverberation Times will cause a build-up of noise and degrade speech intelligibility. If the Reverberation Time is too long the teacher is competing against the lingering reflections of his or her own voice.
Reverberation cannot be overcome by raising the level of the teacher's voice. Although some reverberation may reinforce a teacher's voice, it's a matter of careful balance.



When a room has a high Reverberation Time, sound is received by the listener from all directions at more or less the same volume and the sound level is virtually the same everywhere in the space. When the direction of the sound source cannot be determined, the result is disorientation, which has a negative influence on concentration.

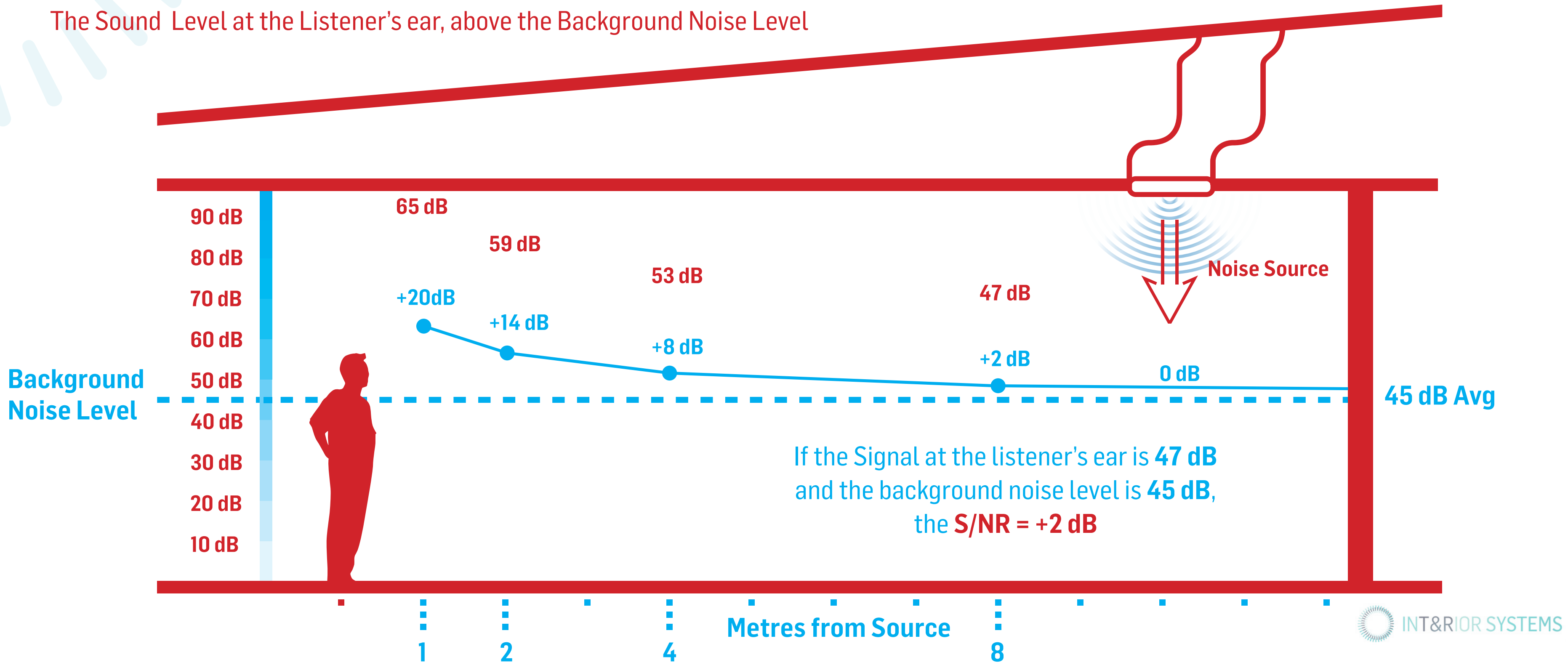
Reverberation Time is often calculated with the room unoccupied. Since people and their clothing provide additional sound absorption, an unoccupied room is the worst-case scenario, though not an unreasonable one, since occupancy of most classrooms varies. In a complete analysis, Reverberation calculations should be performed for each octave band, as the Reverberation Time can vary widely at different frequencies.

[Calculations can be done in advance in order to determine what Reverberation Time can be expected in a proposed new space, [such calculations can be found in the Appendix].

The variables that affect the Reverberation Time within an interior classroom include the volume of the space and the amount of sound absorption within the room. Smaller classrooms generally have shorter Reverberation Times than larger classrooms and spaces with many hard nonporous surfaces are very prone to longer Reverberation Times.

It is the designer or architect's responsibility to ensure that a space meets the required Reverberation Time by providing appropriate amounts of absorptive materials. The absorptive quality of a material is given by its NRC rating (where 1 is complete absorption and 0 is complete reflection).

Signal-to-Noise Ratio



This figure depicts a classroom setting in which the teacher's voice signal is determined to be approximately 65 dB at a distance of 1 metre from the teacher. The background noise level is 45 dB (assumed to be fairly constant through out the room). The Inverse Square Law (See Appendix) suggests that the sound level of the teacher's voice signal will be 59 dB at a 2 metre distance, 53 dB at 4 metres and 47 dB at 8 metres away. In reality, the drop off would be less in most rooms as reflective surfaces add to the signal in the room.

The Signal-to-Noise ratio refers to the ratio of the teacher's voice in relation to the Background Noise at the listener's ear. In other words, it relates to the amount of volume that carries over the Background Noise and can be calculated by taking the sound level of the teacher's voice in dB, minus the background noise level in the room in dB. Obviously the Signal-to-Noise ratio varies throughout the room as the Signal and Background Noise levels vary. The louder the Background Noise, the louder the teacher must speak in order for the students to hear clearly.

The recommended minimum Signal-to-Noise ratio necessary for students to hear efficiently is +12 to +15 dB in all areas of the classroom.

+20 dB is preferred when there are students with hearing impairments. Signal-to-noise ratios generally become less favourable for hearing as the distance between the speaker and the student increases and are typically lowest at the back of classrooms or near a noise source (e.g., HVAC systems or computers) (Seep, Glosemeyer, Hulce, Linn, & Aytar, 2000).

Achieving the recommended ratio is more difficult where the Background Noise level is high and/or the teacher has a quiet voice.

Speech Intelligibility

The Speech Intelligibility Index measures what percentage of speech information, in a given setting is both audible and usable for a listener. Having a Speech Intelligibility Index of 0.5 in an environment means that about 50% of speech cues are audible and usable.

Adults average roughly 10 percent better than children on speech intelligibility tests because they can predict words from context. Students with hearing or learning disabilities, or for whom English is a second language, will show even lower scores.

Speech intelligibility decreases when Background Noise or Reverberation Times increase. When both Background Noise and long Reverberation Times are present in a classroom, they have a combined negative effect on children's listening abilities.

There are many methods for measuring or predicting speech intelligibility, and they are mostly quite complex. However, it can be reasonably well predicted by using the Reverberation Time and Signal-to-Noise Ratio.

If speech intelligibility in a classroom is less than 90 percent, acoustical treatments should be implemented to reduce reverberation and/or improve Signal-to-Noise Ratio.

Measuring speech intelligibility testing is not a simple procedure and seeking professional advice is recommended.

REVERBERATION TIME	SIGNAL-TO-NOISE RATIO	SPEECH INTELLIGIBILITY	
0.5 seconds	+ 10dB	.9	90%
0.5 seconds	+ 0 dB	.55	55%
1.5 seconds	+ 10dB	.75	75%
1.5 seconds	+ 0 dB	.3	30%

As well as issues with speech intelligibility, the combination of high Background Noise and a long Reverberation Time can lead to a situation known as the ‘café or cocktail effect’. This is where all the speakers within the room raise their voice to be heard above the level of Background Noise. As a result, this increases the Background Noise even further as everyone tries to speak ‘above’ the volume of everyone else. The outcome is an extremely noisy environment, which makes it hard to understand what is being said by anyone!

Acoustic Escalator

2 parts vodka
1 part fresh lime
Cranberry juice
Crushed ice
Mint sprig garnish

Shake ingredients hard. Pour through a strainer into chilled Martini glass

Helpful Tips & Guidelines

Helpful Tip:

It is possible to gain a rough measurement of the Background Noise level in an unoccupied classroom with a calibrated noise meter.

Generally measurements should be taken from student desks at the four corners of the instructional area, the middle and the middle back of the room. Additional positions can be added if necessary. Any HVAC equipment should be operating and although the room should be unoccupied, ideally usual activities should be taking place in the rest of the school.

1. Record the number of samples and their duration (e.g., 5 time samples, 1 min each).
2. Determine the average measurement for each location.

To estimate occupied classroom Background Noise levels add another 10 dB to each unoccupied measurement. This conversion is comparable to reported differences in noise levels between average unoccupied and occupied classrooms. This measurement can then be used to calculate the Signal-to-Noise Ratio.

Guidelines

Education Spaces

Type of space	Sound level - dB(A)	Reverberation time - secs
Art / Practical activity	45	0.6 to 0.8
Classrooms, primary	40	0.4 to 0.5
Classrooms, secondary	40	0.5 to 0.6
Computer laboratories	45	0.4 to 0.6
Corridors	50	0.6 to 0.8
Drama studios	35	0.7 to 0.8
Early learning centres	35	0.4
Gymnasiums	55	0.8 to 1.0
Library	40	0.4 to 0.6
Multipurpose Activity Hall	40	0.7 to 0.8
Music practice rooms	45	0.5 to 0.7
Music studios	35	0.7 to 0.8
Offices	45	0.4
Open plan learning areas	35	0.4 to 0.5
Science laboratories	40	0.5 to 0.7
Seminar / Breakout spaces	35	0.6 to 0.7
Staff common areas	45	0.4
Technical studies workshops	45	Technical workshops should have reverberation times minimized as far a practicable for noise control.

Building Code of Australia (BCA)

Australian Standard AS/NZS 2107 Acoustics – Recommended design sound levels and reverberation times for building interiors (2000)

Background Noise Levels

The American Standard, ANSI S12.60-2002, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools

VOLUME OF LEARNING SPACES	ONE-HOUR STEADY-STATE BACKGROUND NOISE LEVELS
< 20,000 Cubic Feet (570 Cubic Metres)	Should not exceed 35 dBA (unoccupied)
> 20,000 Cubic Feet (570 Cubic Metres)	Should not exceed 40 dBA (unoccupied)

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Reverberation Time

The American Standard, ANSI S12.60-2002, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools

VOLUME OF LEARNING SPACES	REVERBERATION TIMES
< 10,000 Cubic Feet (280 Cubic Metres)	Should not exceed 0.6 seconds (unoccupied)
> 10,000 Cubic Feet (280 Cubic Metres)	Should not exceed 0.7 seconds (unoccupied)
> 20,000 Cubic Feet (570 Cubic Metres)	Should not exceed 0.7 seconds (unoccupied)

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Helpful Tip:
The Reverberation Time (RT) within an existing space can be tested with a calibrated Reverberation meter.

A couple of separate measurements should be made in perhaps five different positions (the four corners and the middle of the classroom). The recorded measurements at each position should be averaged to obtain an estimate of the Reverberation Time for that room.

It's important to remember that not all spaces with the same Reverberation Times are the same acoustically as the Reverberation Time varies with frequency.

However, for a quick estimate, the RT of a classroom can be calculated for just one octave band representative of speech frequencies, such as 1000 Hz. If this RT is acceptable, the RT throughout the speech range will likely be acceptable.

Design Solutions

Background Noise

Reverberation Time

- For Standard Classrooms.

Rooms that serve a specific purpose (e.g., gymnasium, music room, library, auditorium) require different acoustic performance standards based on the room's use. Employ an Acoustic Consultant for these spaces.

Please also note that open-plan classrooms may not support satisfactory acoustic conditions and therefore may have a negative effect on the learning process, possibly negating the impact of any desirable effects from teaching methodologies used in open-plan classrooms. The acoustic design of open-plan classrooms needs more rigorous consideration to achieve speech intelligibility that meets relevant standards (UK Department of Education and Skill, in CISCA 2009).

Background Noise

Environmental

HVAC & Electrical

Attenuated Sound

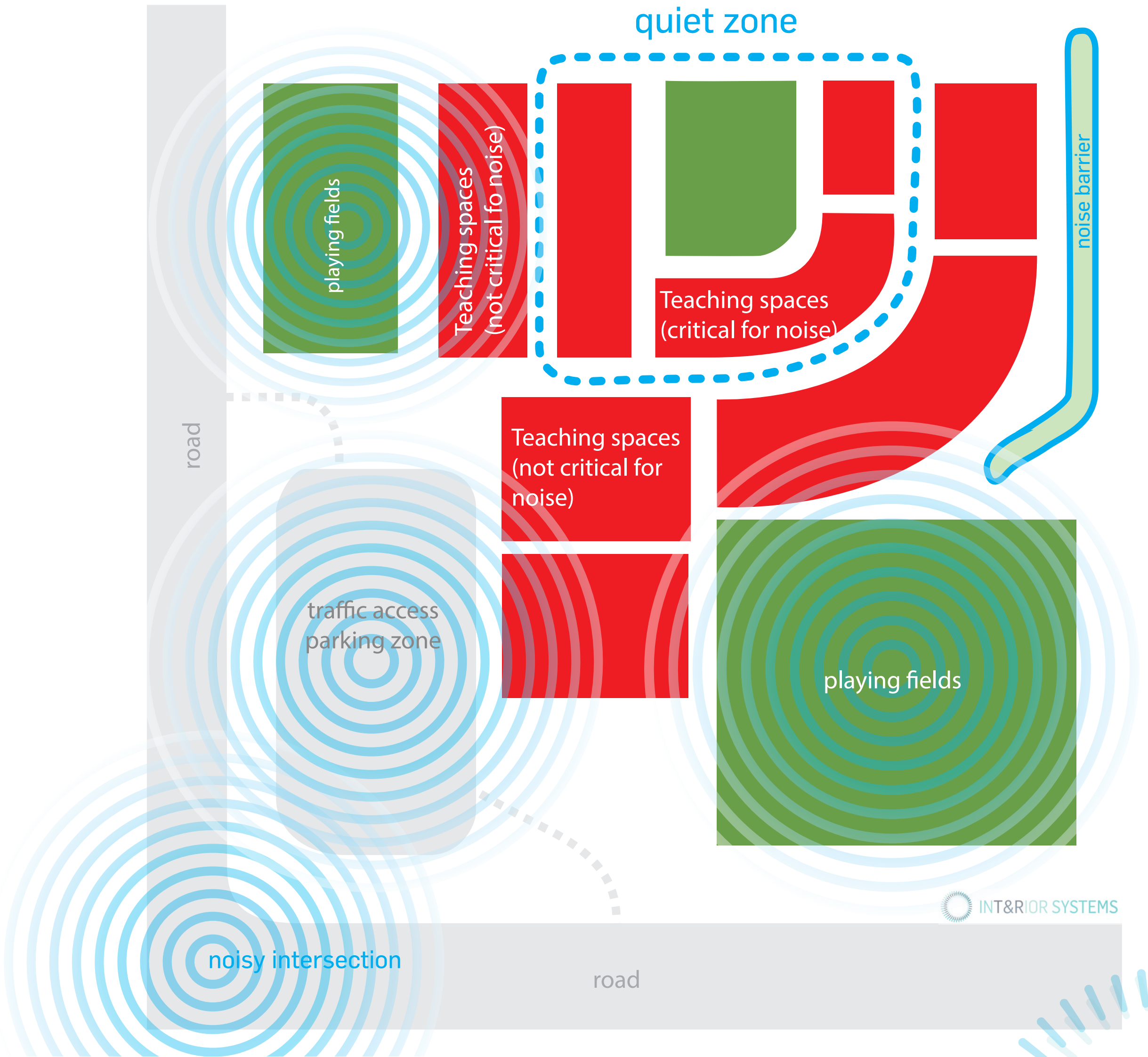
Internal Background Noise

Environmental Noise

Avoid planning traditionally-constructed school facilities on a site where the yearly average, day-night sound level is above 60- 65 dBA. However, ANSI states that with a noise insulating exterior shell, the yearly average, day-night sound level can be 65-75 dBA (Accredited Standards Committee..., 2002).

Once environmental noise sources in the vicinity are identified and the possible impact has been assessed, it is important to minimise or eliminate the potential problem.

The school must be planned so that the least noise-sensitive activities are sited in the areas subject to most environmental noise. Open areas, such as playing fields and staff car parks, should be placed so that buildings are as far as possible from the noise source.

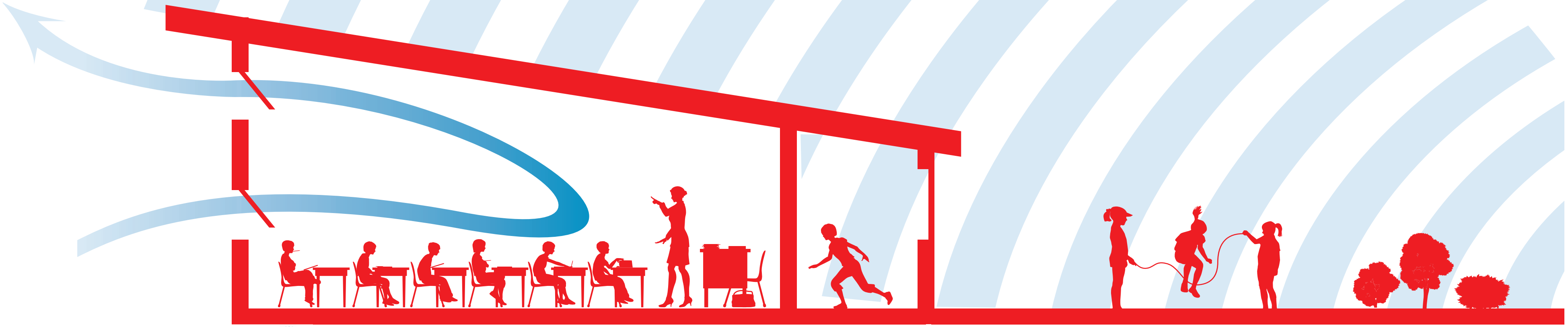


Landscaping measures to reduce traffic noise include the installation of a brick, concrete block or timber noise barrier wall (at least 4 metres high) and/or an earth wall. Trees and foliage don't attenuate sound very well and should not be used as such, but they have diffusing properties which may help reduce reflected sound.

Although a noise barrier wall can be very effective in stopping noise it does not prevent sound passing over the top of the barrier.

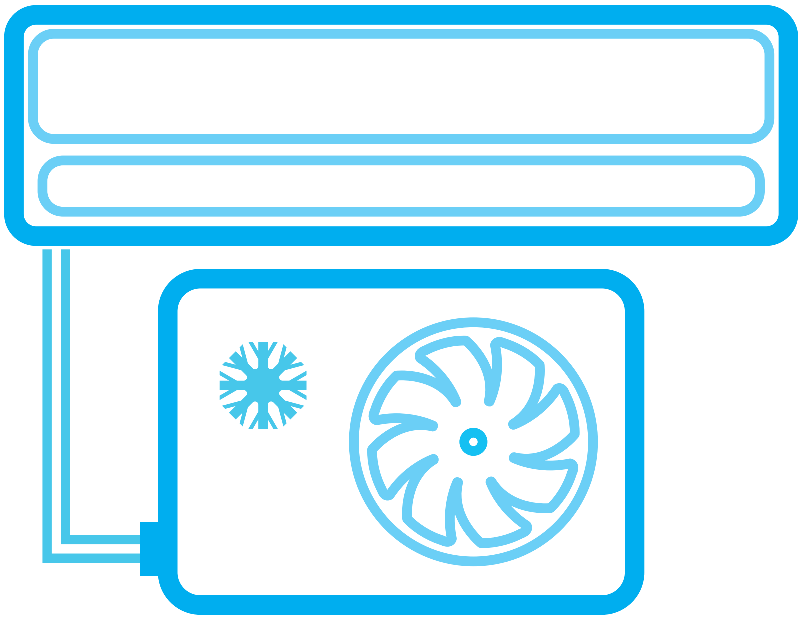
Exterior Walls/Sound Envelope: Where possible, the windows in the teaching spaces should not face the source of environmental noise. If windows are unavoidable they can be designed to attenuate sound, but these are only effective when they are closed. Unless there are windows on the other side of the room that can be opened, mechanical ventilation will be necessary. Physical buffers such as corridors or store rooms are very effective in attenuating Environmental background noise.

The construction of the building envelope will prevent sound coming into the building from the exterior . The effectiveness of the exterior envelope is measured by the STC rating of the given components. As a general rule, the lighter the barrier the more ineffective it will be in preventing the transfer of sound. Theoretically, doubling the mass of the noise-reducing barrier will increase its STC rating by about 5 - 6 dB. (Double-glazing is more effective at attenuating noise than the weight indicates because of the air gap between the two outer surfaces and the performance of a double barrier increases as the gap widens. The addition of sound-absorbing material, such as fibreglass in the cavity, further increases sound attenuation.)



HVAC and Electrical

- A maximum dB level for all equipment in and around the school should be specified
- Operate HVAC systems near their maximum efficiency. Fans are noisier when they are either oversized and operating under design speed, or under-sized and operating above design speed.
- Heating and cooling ducts that serve more than one room should be lined with acoustical materials or equipped with silencers to decrease the transmission of noise between classrooms (Crandell & Smaldino, 1999).
- Rubber supports and flexible sleeves or joints in duct-work systems can reduce the transmission of structurally-borne noise (Crandell & Smaldino, 1999).



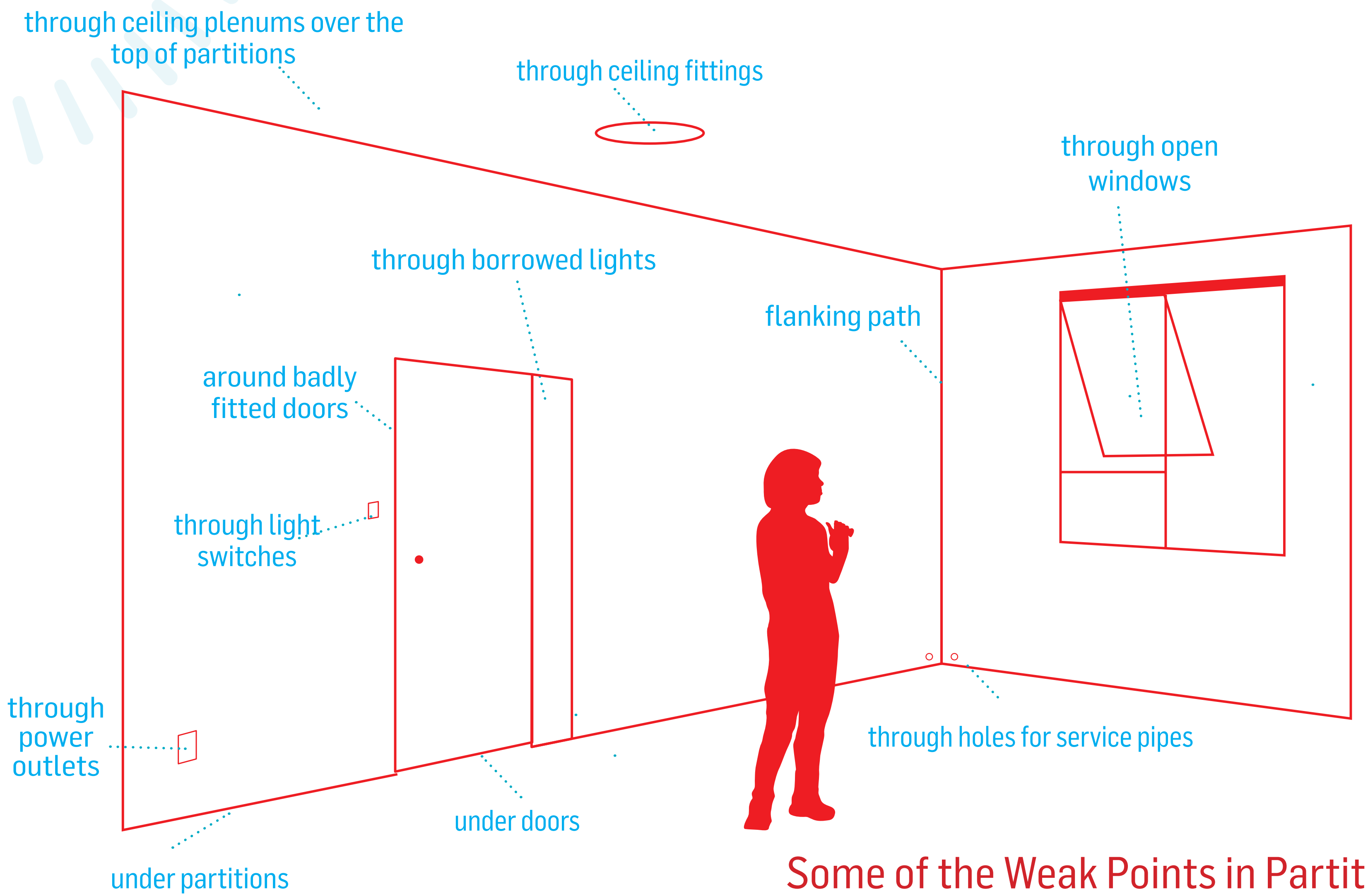
Attenuated Sound

Sound transferred internally between rooms is one of the main causes of high Background Noise levels in classrooms (BRANZ, 2007). The sound insulation provided by a barrier is indicated by the STC rating of the barrier. Identifying a suitable STC rating is the first step in reducing noise between classrooms.

Walls between rooms with noisy and quiet activities respectively will require higher STC ratings than walls between rooms with similar activities. ANSI recommends wall, floor, and ceiling assemblies with a minimum STC rating of 45 in adjacent corridors, 50 STC for general adjacent enclosed classrooms, and 60 STC where one adjacent room is louder (e.g., music room, gymnasium) (Accredited Standards Committee..., 2002).

Sound energy will always travel along the path of least resistance creating flanking paths that allow sound energy to be transmitted into a room. For instance, sound can be transmitted through:

- A single-glazed borrowed light
- An open ceiling plenum above the wall
- Small cracks between the floor and the walls
- Pathways through power outlets, light switches, computer outlets and plumbing pipes, service installations such as electrical outlets and ventilation ducts
- Internal windows
- An open window to outside and back in through another open window



Some of the Weak Points in Partitions

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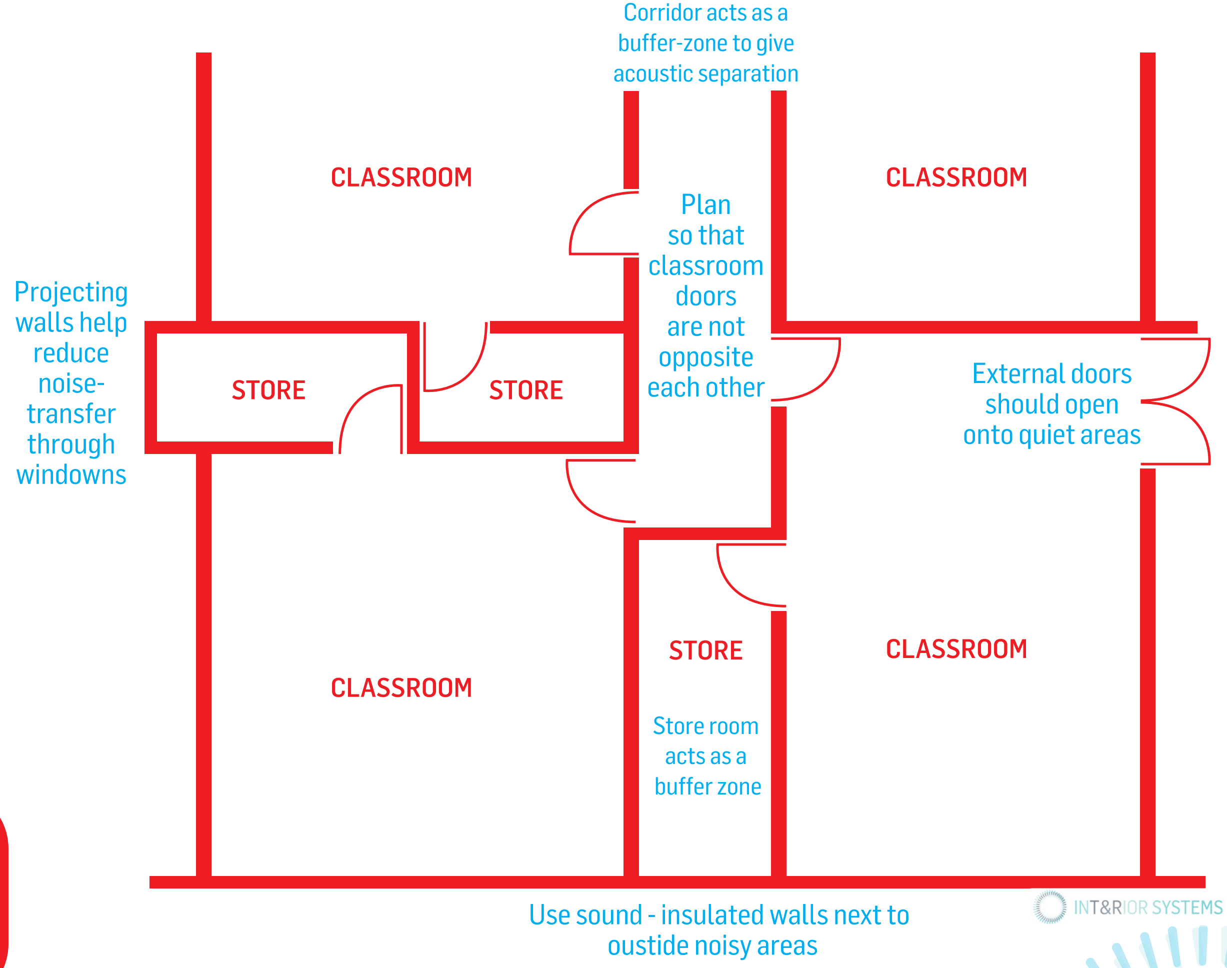
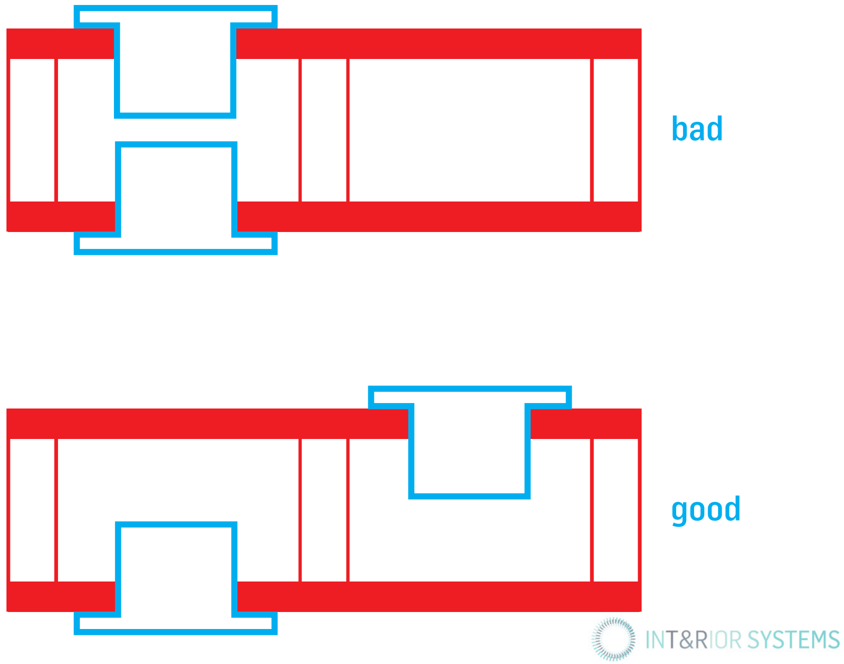
Preventive design can often eliminate the need for thick, expensive walls. During the design process, noisy spaces (mechanical rooms, gyms, tuck shops, music rooms, industrial design workshops, etc.) can be physically separated from learning spaces. Other sound-reducing strategies include using a corridor or storeroom as a buffer or a sound-blocking wall between noise sensitive areas. Furthermore, ensure windows are away from the source of noise.

It is best not to pair up doors to adjacent rooms, as this provides a short path through which sound may travel from one room, through the doors, and into the next room. This also applies to classroom doors placed directly across a hall from one another. Staggering doors across a hallway creates a longer, less direct path for noise to travel from one room to another.



The design should include sufficient barriers between learning environments.

Walls: Breaks in walls such as for power sockets or light switches, heating pipes, computer or phone outlets should be sealed with flexible acoustic sealant. Opening should be staggered along the wall.



Doors are weak points in sound-insulating walls and, in many cases, may be the reason why a wall transmits a large amount noise. Doors in sound-control walls that are not absolutely necessary should be avoided or removed. (This is also true of borrowed lights as these generally have an STC rating of 10 or less). It is important to ensure that seals around doors are correctly installed to eliminate gaps, as these are a common way for sound to pass through a door system. Sound-stop lobbies between doors are effective for sound insulation in certain situations because there are two doors between the sound source and the classroom.

For reference:

A 100mm timber-framed wall with 10mm plasterboard on both sides has an STC rating of 35–38 dB

A 100mm timber-framed wall with two layers of 10mm plasterboard on both sides has an STC rating of 40–42 dB

A 100mm timber framed wall - R1.8 insulation, proprietary resilient rails and two layers of proprietary 10mm acoustic plasterboard has an STC rating of 50+ dB

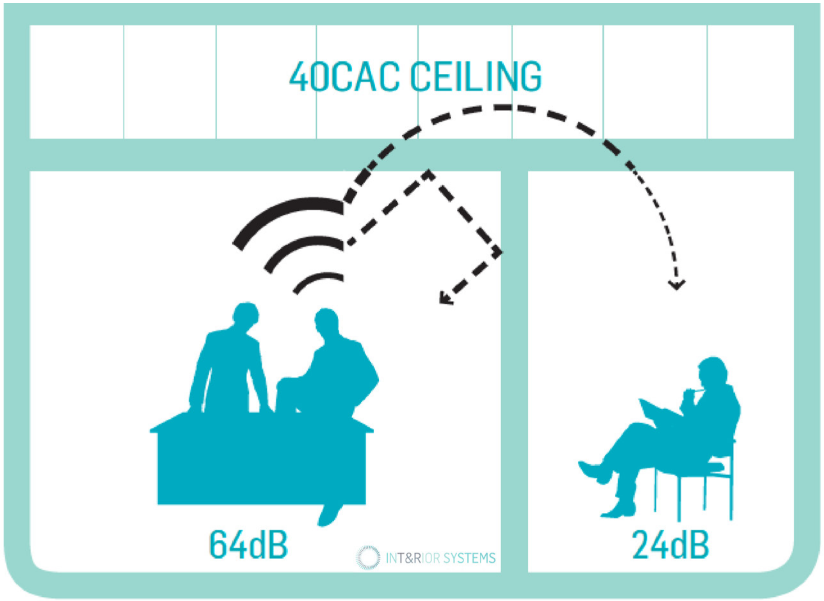
A 100mm timber framed wall with 10mm plasterboard on both sides and an additional timber- framed wall with proprietary 2 layers of 10mm acoustic plasterboard one side, R1.8 insulation, two layers of proprietary 10mm acoustic plasterboard other side has an STC rating of 53 dB.

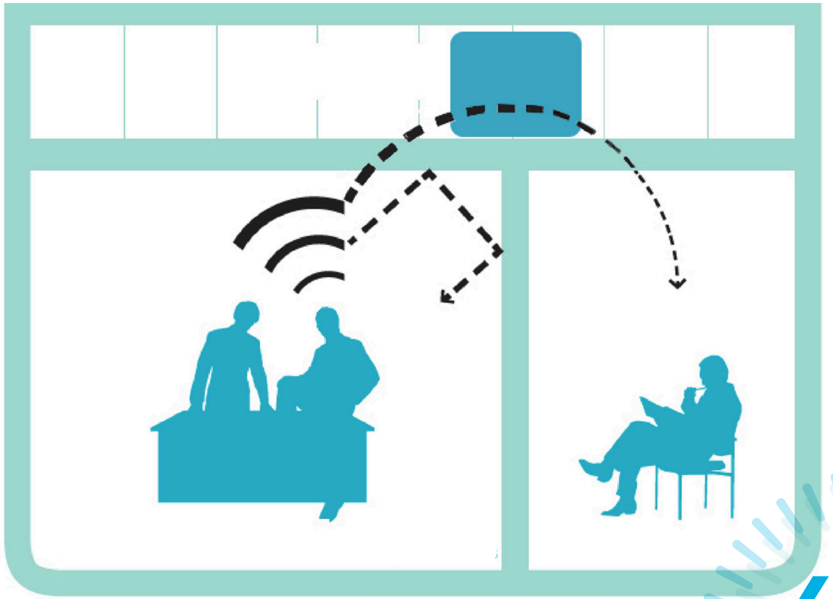
Ceiling- To be effective, partition walls should ideally extend from the structural floor to the structural ceiling. Otherwise, sound from one room can easily pass through the suspended -acoustical- tile ceiling, over the partition wall, and down through the ceiling of the next room. This is commonly overlooked when walls are added during renovations and is especially true when a ceiling tile has a high NRC but a low CAC rating (as is the case with many acoustic ceiling tiles).

If the wall does not extend to the structural ceiling there are a number of methods to reduce the plenum sound path:

- A high CAC rated ceiling tile will reduce the sound transmission between rooms, even if the plenum is open. This can also be achieved with insulation (even thermal insulation has an STC) placed over the ceiling tiles.
- A baffle can be added in the plenum space in line with the walls.

Baffles and a ceiling with a high CAC rating will increase sound attenuation even more.





Internal Background Noise

Internal Background Noise can come from a variety of sources including conversations, whispering, paper rustling, HVAC and computer equipment, furniture legs scraping on a hard floor and students working in groups. Reducing the sources of internal Background Noise is an important starting point for improving the acoustics in the classroom.

Reverberation time is explained with more detail in the following page.

Reverberation Time

However, it's not only the sound created within the space; often it's the reverberation time that intensifies and exacerbates noise. To manage reverberation time, internal noise and provide good acoustic performance within a flexible learning space, the design should typically include the following eight key features:

- Absorptive ceiling treatment (Min NRC 0.85)
- Carpeted floors (The use of acoustic backings further improve their performance.)
- Absorptive wall treatments (equivalent to at least 20% of the ceiling area).
- Adequate spatial volume
- Adequate space per student (user density) Sufficient floor area for each learner (the design should allow 3-4m2 net floor area per learner).
- Mobile furniture modules
- Moveable screens (screens should be a suitable height and positioned to reduce direct sound paths)
- Sliding and/or hinged partitions

- COMPULSORY: An absorptive ceiling treatment (minimum NRC 0.85) must cover the full ceiling area.

Methods include:

- Adding rubber stops to all moveable furniture
- If electronic equipment is used in the classroom, such as computers, separate these where possible, place equipment where noise is minimised (e.g., in an alcove or separate room) and fit sound-absorbent panels to the walls behind and surfaces around noisy equipment
- Install rubber padding under mechanical instruments (e.g., keyboards, printers,) to reduce vibratory noise

Reverberation Time

(Refer to the Sabine Formula in Appendix)

Reverberation time is dependant on

Increase NRC Rated Materials

Increase NRC

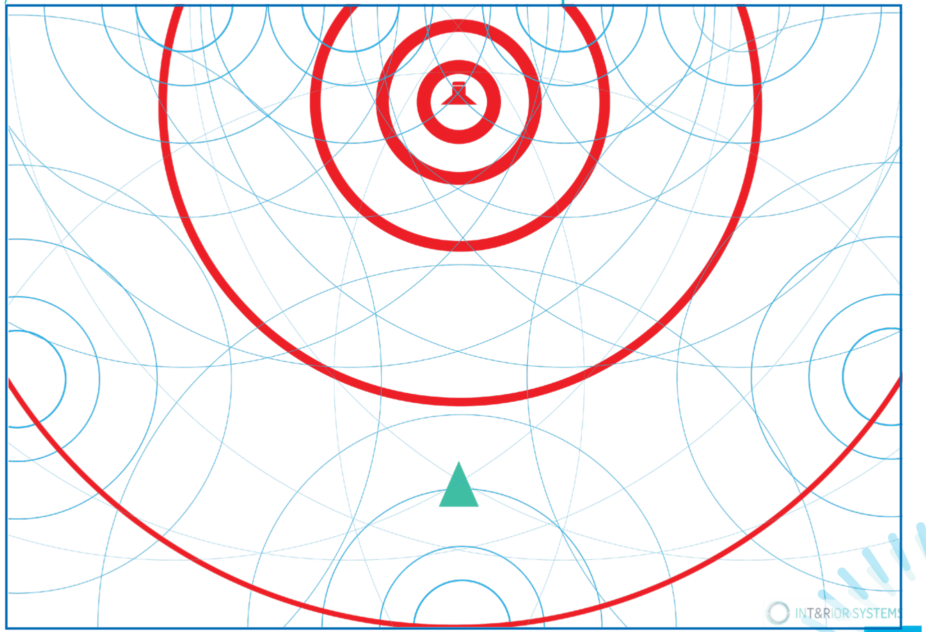
•

Reverberation Time -There are two ways to reduce the Reverberation Time of a room: either the volume must be decreased or the sound absorption must be increased.

Increasing the absorption in a room is accomplished by adding more materials with high NRC ratings, such as fabric-faced glass-fibre wall panels, carpet, or acoustical ceiling tiles.

The American Standards (ANSI S12.60-2002) state that as a general rule, in classrooms without a fixed lecture position

With ceilings more than 3 metres in height, some sound-absorbing materials on the wall must be considered in addition to an acoustic ceiling. Installing sound-absorbing wall panels will also help to lower Reverberation Times in especially problematic rooms (e.g., high ceilings, many windows) (CISCA).

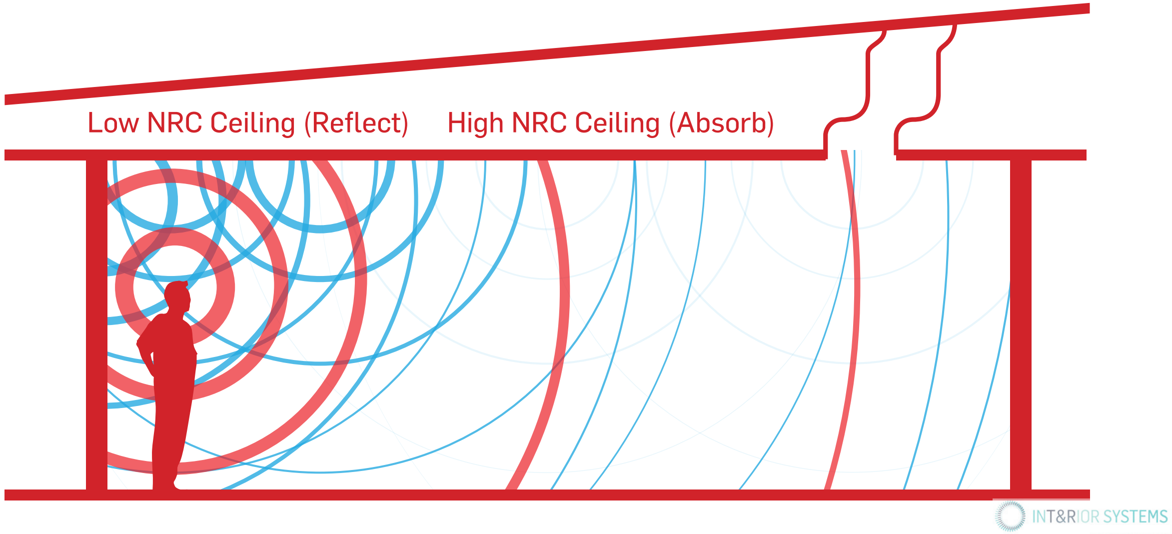


Layout of NRC Materials

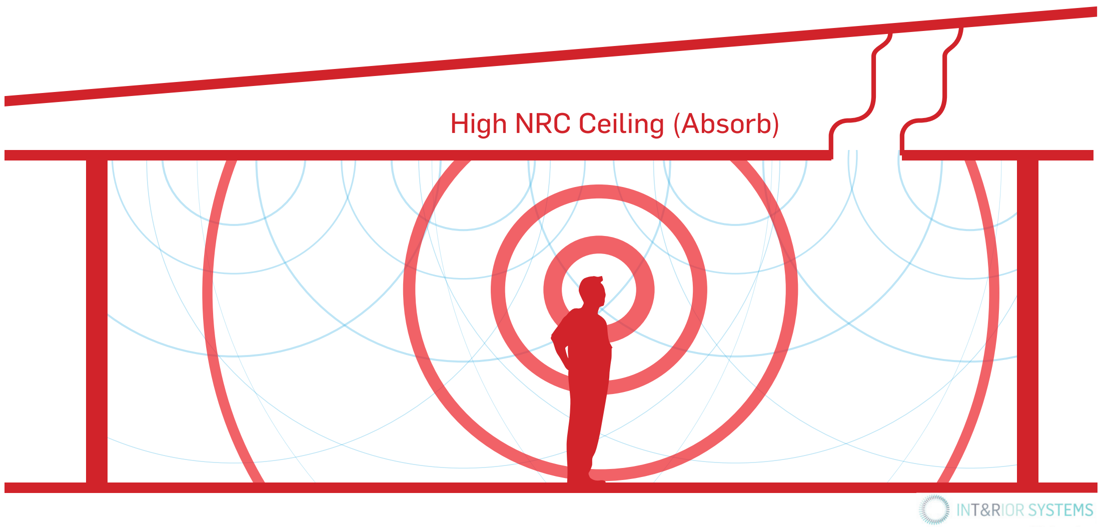
For lecture theatre type layouts only. (Not applicable in ILEs.)

It is important to aim for optimal reverberation times and this is the main priority. However, the layout of the high NRC materials is not always obvious. Considering the Signal-to-Noise Ratio diagram and Inverse Square Law, it is clear that a complete lack of reflected sound does not help the teacher; the absorbent ceiling can absorb the sound energy of the teacher's voice before it reaches students at the back of the room. Methods for reducing reverberation in classrooms is achieved with high NRC rated products, but in some cases it may be good to reinforce certain sound paths by using reflective surfaces with low NRC ratings! This is especially true in large classrooms that have short reverberation times.

The teacher's voice can be spread throughout the room by shaping a sound-reflecting ceiling over the front of the room, or by making the centre of the ceiling a hard, reflecting surface. These surfaces will reflect sound toward the rear of the room. In order to maintain a low reverberation time with reflectors in the room, it will likely be necessary to add absorptive materials on the side and rear walls. Simply put, in classrooms with fixed lecture positions, avoid placing high NRC rated materials directly above or in front of the teacher's lecture position (Accredited Standards Committee..., 2002). Placing an absorptive material on the rear wall of a classroom prevents the teacher's voice from reflecting back to the front of the room. While absorption is one way of minimizing reflected energy into the classroom, another approach is diffusion. Placing a diffusing element on the rear wall of the classroom scatters the sound into many directions, so that the sound level in any one particular direction is greatly reduced.



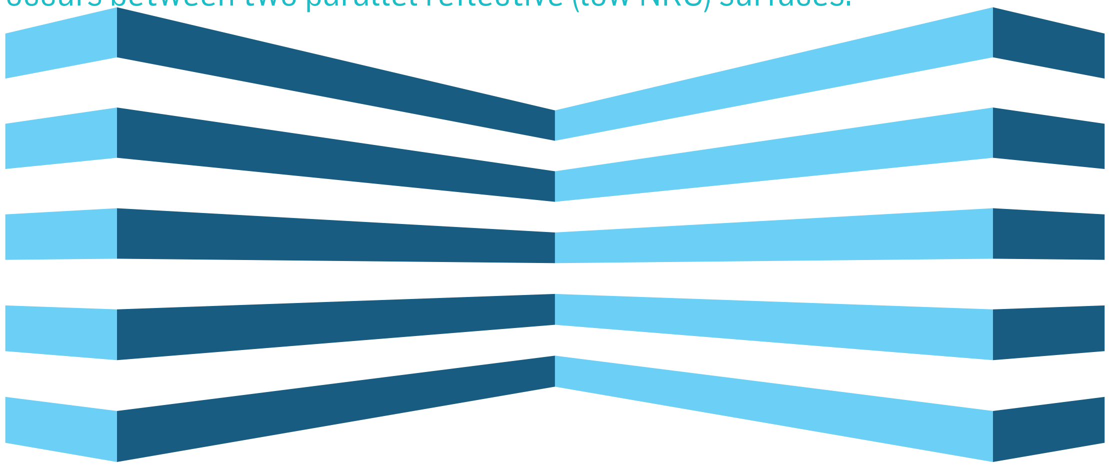
Reflective surfaces at front of classroom helps teachers to project their voice to back of the room.
High NRC surfaces on the rest of the ceiling prevent further reverberation.
(This is only effective in lecture style layouts.)



Floors- Simply adding carpeting to a classroom floor will not significantly reduce Reverberation Time, especially at low frequencies, but carpeting will reduce Background Noise resulting from students sliding their chairs or desks on the floor. An acoustic underlay significantly improves acoustic absorption performance.

Walls - Although an acoustic ceiling and carpeted floor does nothing to control echoes from the walls, the thoughtful arrangement of furniture such as cabinets and bookcases can help break up large, flat walls and reduce echoes. This solution is inexpensive for new construction and is also an affordable way to renovate existing classrooms.

Echoes interfere with speech intelligibility and can be controlled using absorption and/or diffusion. When choosing Flutter echo is a particularly significant problem when it occurs between two parallel reflective (low NRC) surfaces.



Simple solutions include adding Pin boards and sound absorption panels to classroom walls.

The DQLS recommends wall covering to be at least 20% of the ceiling area.

A simple way to test whether flutter echo is a problem is to stand near the centre of the classroom between parallel surfaces, and clap hands once sharply. If flutter echo exists, a zinging or ringing sound will be heard after the clap as the sound rapidly bounces back and forth between the two walls.

To eliminate flutter echo between two hard, parallel walls, cover one or both of them with a high NRC material. This works well if the panels are staggered along the opposite walls so that a panel on one wall faces an untreated surface on the opposite wall. Splaying two walls at least eight degrees out of parallel will also eliminate flutter echo between them. Alternatively, positioning large reflective surfaces (e.g., blackboards, glazing) at nonparallel angles to the walls will also help to reduce echoes.

Where the traditional lecture style layout (teacher at the front) is the main teaching style, placing sound-absorbing materials on the rear wall of classrooms will prevent sounds from echoing to the front of the classroom. It will also eliminate discrete echoes and improve classroom speech intelligibility (Seep et al.,2000).

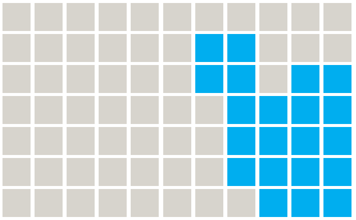
Ceilings - In order to absorb both low and high frequency sounds, it is better to suspend the ceiling below the structural ceiling as the performance of sound-absorbing materials (e.g., suspended acoustical ceilings) is generally improved when mounted with an air space behind them. Although an air space/ ceiling plenum creates another sound path for sound attenuation, this can be addressed by taking the walls to the structural floor above; adding acoustic baffles and/or adding tiles with a high CAC.

Ceiling tiles will not address the problem of echoes from the walls. However, if all sound-absorbing material in a classroom is on the ceiling, place bookshelves along the wall to reflect sound waves in the direction of the ceiling (Accredited Standards Committee..., 2002).

Consult professionals when reverberation from frequencies less than 500 Hz are a concern (Accredited Standards Committee..., 2002).

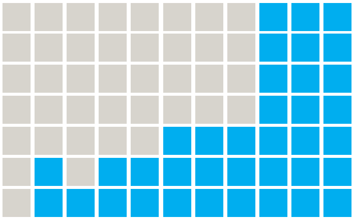
ANSI recommends installing a suspended ceiling with an NRC of 0.7 or higher that covers the whole ceiling surface area, excluding ventilation grills and light fixtures in large learning spaces with ceilings 3 metres high or lower, (Accredited Standards Committee..., 2002).

BRANZ recommends the following



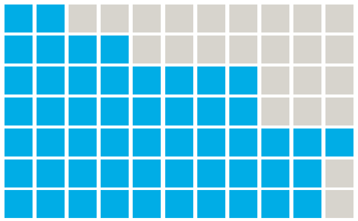
40% of ceiling area with acoustic tiles

In new or existing classrooms with floor areas of 100m² or less, install ceiling tiles with an NRC of not less than 0.7 over 40% of the ceiling.



60% of ceiling area with acoustic tiles

In new or existing classrooms with floor areas of 100m² or more, install ceiling tiles with an NRC of not less than 0.7 over 60% of the ceiling.



80% of ceiling area with acoustic tiles

In existing classrooms glue and staple mineral fibre tiles with an NRC of of 0.5 to 80% to the ceiling.

(Not indicative of layout)

INT&RIOR SYSTEMS

General Design Tip:
Corridors, stairs and other spaces where there are a lot of teachers and students moving about are noisy. If these spaces are treated to reduce noise and reverberation, this will give the whole school a quieter feel. It will also reduce the amount of noise transferred into teaching spaces, although ensuring that doors and windows that open from the corridor into teaching spaces have good sound insulation properties is also advisable.

Amplification Systems

Situations may arise where it is not possible to achieve satisfactory classroom acoustic conditions for all users. There may be a variety of reasons for this:

- Outside noise is too loud to be sufficiently and economically controlled
- The teacher's voice is not strong enough to achieve a satisfactory voice-to-background noise ratio
- The class has students:
  - with hearing impairments;
  - for whom English is a second language
  - with learning difficulties.

Teacher's voice amplification systems may be necessary in situations such as these. They should be specified and installed by professionals and work best in spaces that are acoustically well designed. They are not a substitute for good acoustical design and should only be used when all other options have failed. Sound levels should not exceed 80 dB at any time and never exceed a level of 70 dB over the teaching period.

Appendix

Inverse Square Law

In the real world, the inverse square law is always an idealisation because it assumes exactly equal sound propagation in all directions. If there are reflective surfaces present, then reflected sounds will add to the directed sound and you will get more sound at a field location than the inverse square law predicts. If there are barriers between the source and the point of measurement, you may get less than the inverse square law predicts. Nevertheless, the inverse square law is the logical first estimate of the sound you would get at a distant point in a reasonably open area.

It states that for every doubling of distance, the sound level drops by 6 dB.

Sabine equation

Sabine's reverberation equation was developed in the late 1890s in an empirical fashion. Sabine established a relationship between the RT60 (the time it takes for a sound to reduce by 60 dB after it ceases), the space's volume, and its total absorption (in sabins).

This is given by the equation:

$$T_r = 0.161 \frac{V}{A}$$

The Reverberation Time (Tr, in seconds) is directly proportional to the volume of the room (V, [m3]) and inversely proportional to the room's effective surface area (A, [m2]).

The effective surface area is the sum of the product of an area covered by a particular material and the material's absorption coefficient. Essentially calculating the percentage of absorption of the floor, the walls and the ceiling...

$$A = \sum_{i-1}^{x} a_i A_i = a_1 A_1 + a_2 A_2 + a_3 A_3 + \ldots\ldots$$

The units of A are sabins.

The total absorption in sabins (and hence Reverberation Time) generally changes depending on frequency (which is defined by the acoustic properties of the space). The equation does not take into account room shape or losses from the sound travelling through the air (important in larger spaces). Most rooms absorb less sound energy in the lower frequency ranges resulting in longer reverb times at lower frequencies.

Using the Sabine Formula:
Modelling a 100m2 room with a ceiling height of 3m with the following absorption coefficients: (Calculated at 1000Hz)

Walls; NRC = .09 (Plasterboard)
Floor; NRC =.3 (Carpet)
and Ceiling; NRC =.75 (acoustic ceiling tile 100%)
for average of aavg =.36 which gives an Effective Surface area of A =115.8m2
Volume V = 300m3.

INDICATION POSSIBLE	INTERVENTIONS
High background noise level from outside sources	Improve acoustic performance of façade, or shield façade from noise source
High background noise level	Remove, replace or mitigate sound source(s)
High background noise level from adjacent spaces	Reduce reverberation time by installing absorptive panels/materials spaces AND improve acoustic performance between spaces
Excess reverberation	Reduce reverberation time by installing absorptive panels/materials
Teachers find it difficult to project their voices	Reduce internal background noise AND consider acoustic reflectors (specialist advise required)
Some students have hearing impairments	Reduce internal background noise AND reduce reverberation time AND consider an assistive devise(for example, FM/Bluetooth)

Sources

The corresponding Reverberation Time is RT60 = .42 seconds. (Low Reverberation Time)

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