



A Comparative Assessment of Educational Acoustic Design Guidelines against NSW EFSG

Jorge Reverter Garcia (1) Shahrokh Sepehriahnama (1), and Joseph Milton (1)

(1) Acoustic Group, JHA Consulting Engineers Pty Ltd, Level 20, 2 Market Street, Sydney, NSW 2000, Australia.

This paper conducts a comparative assessment of the acoustic design considerations of the School Infrastructure New South Wales (SINSW) Educational Facilities Standard Guideline (EFSG) alongside nationally and internationally recognised guidelines for educational facilities. From the analysis, shortcomings stemming from an outdated guideline, as well as gaps in design clarity were identified. Areas lacking updates of best practices are highlighted and potential improvement for the mandatory EFSG acoustic criteria are recommended. Additionally, the acoustic design specifications were thoroughly examined from the viewpoint of ambiguity and potential overdesign, buildability and associated cost. The outcomes of this comparative assessment signify the importance of fostering a constructive dialogue between design team and stakeholders to establish an improved acoustic guideline that will create innovative and sustainable acoustic environments that considers user's needs and enhance the functionality of educational spaces.

1 INTRODUCTION

Over the past few years NSW has seen steady population growth across the state, with much focused around the Greater Sydney Area. With population figures projected to rise further still there has been a concerted effort to upgrade existing and establish new public educational spaces to deal with increasing student numbers.

The functionality of educational buildings and their spaces is directly associated with the acoustic design. Common acoustic issues such as appropriate background noise levels, reverberation times and the sound insulation performance of the partitions are critical in establishing an effective learning environment. Other considerations include but are not limited to speech intelligibility, speech privacy and noise intrusion.

School Infrastructure New South Wales (SINSW) is the key authority for primary and secondary public educational facilities in NSW. SINSW has established an Educational Facilities Standard Guidelines (EFSG) which is intended to provide minimum design requirements and guidance to the design team. Within EFSG there is a specific section for acoustics, previously known as DG-11 (EFSG-DG11, 2010) which has recently been updated to Acoustic Checklist 0001c (Design Checklist, 2023) in the latest revision, EFSG V2.0.

Based on the current acoustic design guideline, acoustic consultants involved with public school projects in NSW are faced with a guideline that has unclear criteria, has gaps in design criteria and uncertainty in the acoustic design. This can lead to acoustic conditions that interfere with effective teaching and learning. Furthermore, the acoustic guideline provides design advice that can result in underperforming or overdesigning solutions which can ultimately impact on the cost of the building. This issue is currently resolved by requesting departures from the guideline which ideally should not be sought when designing to a comprehensive and thorough guideline.

2 ACOUSTIC DESIGN IN EDUCATIONAL SPACES

The purpose of a comprehensive guideline is to establish various criteria which are typically derived from other relevant guidelines, plus experience from finalised projects.

Acoustic standards and guidelines for educational facilities should provide design criteria and guidance for typical noise scenarios, as depicted in Figure 1. These common scenarios, while representative, are not exhaustive of all acoustic design considerations for educational facilities. Overall, in the reviewed guidelines, Internal Noise Levels (INL), Reverberation Time (RT) and Acoustic separation (ACI) within buildings are discussed generally; however, others such as external noise impact, particularly traffic noise, are either missed or partially mentioned.

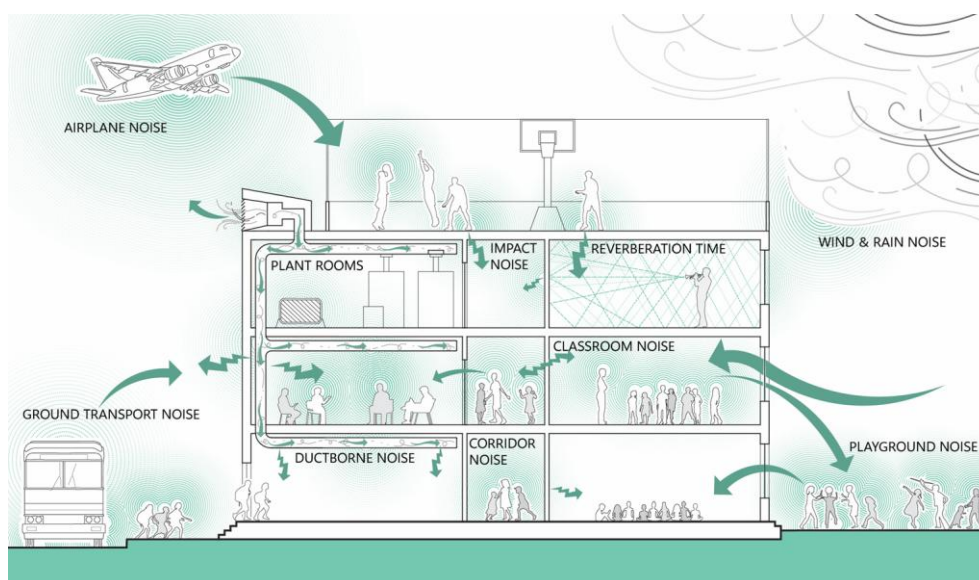


Figure 1 – Typical noise scenarios for an educational building from internal and external sources and noise transfer paths between spaces.

The goal of the acoustic design of a learning space should be to provide an appropriate acoustic environment for communication between teachers and students. General Learning Areas (GLAs) and other specialised learning spaces are the primary spaces where students learning is directly affected by the acoustic environment. Good acoustic design of GLAs can enhance students learning, for example, the design allows for students to clearly hear and understand the teacher and each other well (Shield & Dockrell, 2003; Cheryan et al, 2014). This is associated with Speech Intelligibility (SI), implying a listener's level of understanding when others speak (Whitlock & Dodd, 2006), in the presence of high INL. Generally, in a classroom, a low SI can lead to misunderstanding, frustration and eventually less learning by students. The same rationale applies to non-typical learning areas, for example, Sports Halls and Music Rehearsal Rooms where specific criteria based on the number of users, volume of the room and functionality are key for the design of these spaces. In other spaces, such as a Library Study Area, the level of acoustic comfort, e.g. quietness, is the key design objective. Workshops and Science Laboratories also require a controlled noise level, accounting for all internal and external noises, to support an optimal learning environment.

Older learning spaces traditionally consisted of square or rectangular classrooms with highly sound-reflective finishes on the walls, floors and ceilings. These spaces had poor sound insulation performance of the building envelope, resulting in increased vocal effort from the teaching staff. Departing from this form of closed classrooms, in modern schools, the open-plan classrooms have been adopted to accommodate more students and encourage students' collaborative learning. However, a recent study (Gary Rance, 2023), NSW Teachers Union (Harris, 2023) and current public feedback (Carrol, 2022) have shown that the learning of students has been adversely impacted due to the noise issues from students' activities obstructing teachers' delivery of lessons. Since the classroom function is almost the same, standards and guidelines must specify the acoustic criteria with respect

to other design considerations to achieve the optimal acoustic condition in the conventional and open-plan learning spaces.

Considering the broad range of acoustic requirements for learning and teaching, it is necessary to assess in detail the current guidelines, specifically in the context of NSW School Infrastructure, and identify any gaps that can be improved in the future revisions.

3 OVERVIEW OF ACOUSTIC GUIDELINES FOR EDUCATIONAL FACILITIES

The previous revisions of EFSG DG-11 (latest dated 2021) and the current version (Design Checklist, 2023) under EFSG V2.0 provided almost identical sets of criteria and construction recommendations. In our opinion, further advice from the acoustic consultant community should be considered to improve and further develop the EFSG Acoustic Checklist to meet users' needs and expectations.

The Australian Standard AS/NZS 2107 provides a generic set of criteria for Internal Noise Levels (INL) and Reverberation Times (RT) in different types of educational spaces (AS/NZS 2107, 2016). For their first version, the Association of Australasian Acoustical Consultants (AAAC) adopted earlier versions of AS/NZS 2107 and the Building Bulletin 93 (BB93) from UK Department for Education to establish more specific guide notes and criteria, including the Speech Intelligibility design (AAAC, 2018). The earliest version of AAAC guidelines for educational facilities was used to develop the NSW EFSG-DG11 in 2010, setting almost the same criteria for INL and RT, but less accurate Speech Transmission Index (STI) criteria with respect to space types.

Other Australian states have also established their own guidelines, e.g. Queensland (EFTS-Section5, 2024), and Victoria (BQSH-Section5.5, 2024). They include additional information to those in the AAAC guidelines in terms of INL, and RT, and ACI criteria (AAAC, 2018). Outside Australia, United Kingdom (BB93 Acoustics of Schools, 2015) and New Zealand (DQLS, 2023) are example countries implementing comprehensive guidelines for educational facilities, based on similar acoustic criteria with more detailed specifications of design and construction. A comparative assessment of these guidelines against EFSG is presented in the following Section.

4 DETAILED REVIEW OF EXISTING GUIDELINES

This Section presents a review the EFSG acoustic design parameters in comparison to other guidelines to identify potential areas for improvement, initiate a dialogue to rationalise the acoustic design requirements and proposed design solutions for public educational facilities in NSW. The guidelines are compared against each other in terms of INL, RT, ACI, External Noise Intrusion, and STI. Since the AAAC guidelines were derived from several international sources and is applicable to Australia, it is considered as the reference for this comparative assessment. To achieve a suitable acoustic environment, the guideline could be enhanced by including further detailed recommendations based on the outcomes of the following reviews.

4.1 Acoustic Insulation (ACI) Criteria

It is critical to address the ACI for public educational spaces as this will directly affect the suitability of a space for learning as well as impact the construction cost. All guidelines except the DQLS for New Zealand establish the ACI criteria based on the activity noise levels in a room (source) and the tolerance to noise in the adjacent room (receiver). Noise levels are qualitatively categorised from low to very high for the source room and very low to high for the receiver room. The ACI ratings from all guidelines are given in terms of in-Situ Sound Insulation rating D_{nTw} . This includes converting the NZ criteria values from STC ratings to D_{nTw} by subtracting 5dB, which is the typical correction applied by industry. Table 1 shows the ACI criteria for each guideline and has been colour coded to highlight the differences with respect to the AAAC D_{nTw} ratings. Green indicates the rating is equal to AAAC, red indicates the rating is +10dB, orange indicates the rating is +5dB and blue indicates the rating is -5dB.

Table 1 - Review of ACI of walls and partitions in D_{nT_w} .

| Noise Tolerance in receiver room | Noise level in the source room | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------------------|--------------------------------|------|------|------|----|----|---------|------|------|------|----|----|------|------|------|------|----|----|-----------|------|------|------|----|-----|
| | Low | | | | | | Average | | | | | | High | | | | | | Very high | | | | | |
| | AAAC | EFSG | BQSH | EFTS | UK | NZ | AAAC | EFSG | BQSH | EFTS | UK | NZ | AAAC | EFSG | BQSH | EFTS | UK | NZ | AAAC | EFSG | BQSH | EFTS | UK | NZ |
| High | 30 | 25 | --- | --- | 30 | 40 | 35 | 30 | 35 | 35 | 35 | 40 | 40 | 40 | 45 | 45 | 45 | 50 | 45 | 50 | 50 | 55 | 55 | --- |
| Medium | 35 | 30 | 40 | 40 | 35 | 40 | 40 | 35 | 45 | 45 | 40 | 45 | 45 | 45 | 50 | 50 | 50 | 50 | 50 | 50 | 55 | 55 | 55 | --- |
| Low | 40 | 35 | 45 | 45 | 40 | 40 | 45 | 40 | 50 | 50 | 45 | 50 | 50 | 50 | 55 | 55 | 55 | 55 | 55 | 50 | 55 | 55 | 55 | --- |
| Very Low | 45 | 40 | --- | --- | 45 | 40 | 50 | 45 | --- | --- | 50 | 50 | 55 | 50 | --- | --- | 55 | 55 | 60 | 55 | --- | --- | 60 | --- |

Comparing all guidelines, the EFSG is the least stringent being equivalent to or lower than AAAC. The UK guideline is most similar to AAAC, and the BQSH and EFTS guidelines are more stringent than AAAC by across all noise level categories. Furthermore, the UK and NZ guidelines provide design recommendations of an optimal wall system to achieve the required ratings. The NZ guideline sets the criteria directly with respect to the room type and includes exceptions where noise levels are higher in the source room. UK guidelines provide comprehensive details about wall systems with required wall linings to meet the ACI criteria.

4.2 Internal Noise Level (INL) Criteria

Criteria for the background internal noise levels in terms of L_{Aeq} are shown in Figure 2. It should be noted that the more stringent the criteria are in the guidelines, the higher the associated costs are for the noise controls from building services, façade construction, etc (Deb James, 2012).

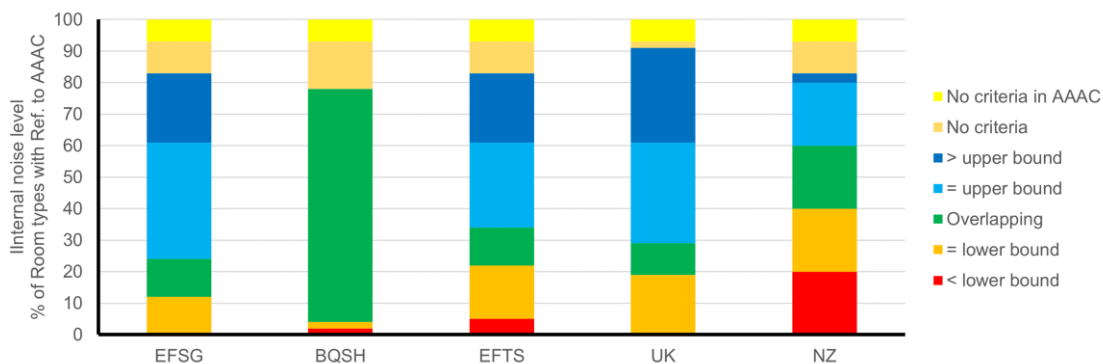


Figure 2 – Comparing INL criteria values with respect to AAAC for different guidelines. Percentage of room types is shown for each category. Red and blue shading corresponds to more stringent and less stringent criteria, respectively. The upper bound and lower bound are from the range established by AAAC guideline.

The New Zealand guideline specifies the least stringent criteria for the INL, while EFTS and UK guidelines are the most stringent. BQSH matches in 74% of cases with the AAAC criteria, and EFSG criteria are more stringent than AAAC for 60% of the spaces.

Improvement in the EFSG in terms of INL, e.g., increasing it by 5dB for less critical spaces, can contribute to infrastructure cost savings for educational facilities. An optimal criterion should consider requirements of appropriate Signal to Noise Ratio (SNR) in different spaces, rain noise levels and the break-in noise from ground traffic and aircraft noise.

4.3 Reverberation Time (RT) Criteria

A comparison of the RT criteria in terms of RT_{mid} is shown in Figure 3. It should be noted that the more stringent the RT criteria are in the guidelines, the higher the associated costs are for the larger quantities or higher performing sound absorptive finishes.

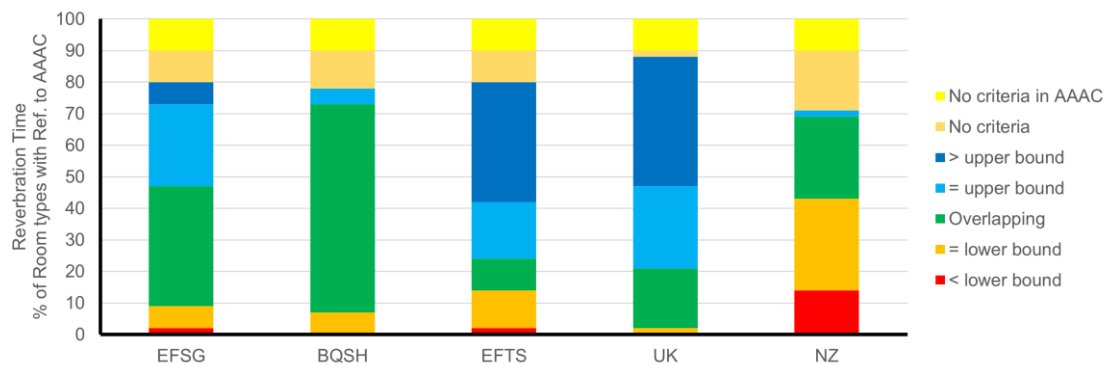


Figure 3 – Comparing RT criteria values with respect to AAAC for different guidelines. Percentage of room types is shown for each category. Red and blue shading corresponds to more stringent and less stringent criteria, respectively. The upper bound and lower bound are from the range established by AAAC guideline.

The results show that the EFSG criteria is identical or less stringent than the AAAC criteria for approximately 64% of room types. The New Zealand guidelines are the most stringent for more than 40% of room types, which implies more sound absorptive finishes, and a higher cost would be required to achieve the RT criteria. The BQSH is the closest to the AAAC, and the EFTS is the least stringent for 60% of the space. Since better speech intelligibility requires an optimal RT, this part of the EFSG can be improved by adjusting the criteria with respect to the speech requirements, in conjunction with the INL (Mealings, 2016).

4.4 Speech Transmission Index (STI)

EFSG V2.0, and its previous version, have outlined criteria for Speech Transmission within spaces in educational facilities. However, the values for STI criteria appear to be taken from the RT Criteria, which are unfit for this purpose as the STI has an upper limit of 1 (with no physical unit) whereas the RT can exceed 1s. Furthermore, there are also criteria for STI as an independent parameter, which is misleading since STI is a relative measure and dependent on the source, receiver and ambient sound levels; thus, presented as an index ranging between 0.0 to 1.0.

UK guideline provides criteria only for open-plan learning areas to be $STI > 0.6$, compared to AAAC criteria of $STI > 0.7$. AAAC also provides STI criteria for spaces with larger volumes and relatively higher RTs, e.g., Auditoria, Gyms, and Multipurpose Halls. VIC, QLD and NZ guidelines lack STI criteria; however, its importance in the context of schools and educational facilities is emphasised.

Furthermore, since testing SI for one area requires several measurements to cover different scenarios, particularly for open-space classrooms, an acoustic guideline should provide practical recommendations to achieve a qualitatively reasonable SI, by adjusting the criteria for INL and RT.

4.5 External Noise Intrusion

The noise intrusion from external sources is considered in all different guidelines. EFSG V2.0 refers to other environmental guidelines including State Environmental Planning Policy (SEPP-2007), AS2021:2015 for aircraft noise, and NSW Noise Policy for Industry (NSW NPI) for methods of assessment of noise from external sources. Hence, a direct comparison with other guidelines is not possible. The AAAC guideline incorporates the required external noise break-in in the criteria for the INL and provides high-level advice about controlling external noises in general. Others provide more detailed advice on controlling road, rail and aircraft noises or include specific criteria for external noise intrusion into different spaces within educational facilities, including criteria for rain noise intrusion for various rain event intensities.

5 OTHER IDENTIFIED ISSUES IN EFSG

The comparison between guidelines up to here was in terms of common acoustic criteria. However, the following issues were found through a comparative assessment against EFSG. This analysis aimed to identify gaps and incomplete areas in the EFSG V2.0, highlighting potential enhancements for future revisions.

5.1 Criteria for Rain Noise

Whilst the EFSG provides advice to assess the design rainfall in general learning areas, music, drama, movement studios and halls, it does not specify INL during rain events. BQSH recommendations can be helpful for the design to address rain noise. The BQSH requires the rain noise during a moderate rain event (up to 25mm/h rate) not exceeding the internal noise levels by more than 5dB(A) within learning and speech areas.

EFSG V2.0 would benefit from recommendations for typical lightweight roofing systems as in other guidelines, according to the intensity of the rain events, as a guide for implementing appropriate controls for rain noise. A useful reference can be the NZ guideline, which provides recommendations for ceiling systems such as 150mm ceiling cavity plus CAC 40+ ceiling lining or 150mm cavity plus insulation batts and CAC 35+ ceiling lining for high rainfall rate areas (>20mm/hr). These lightweight roofing for rain noise controls are also required to mitigate aircraft or helicopter noise intrusion when the schools are near an airport or a hospital flightpath.

5.2 Doors, Windows and Openable Partitions

Doors, windows and openable partitions are typically the weakest ACI performing element in a partition. To maintain an adequate ACI performance in partitions with doors, the composite sound insulation rating should be considered. EFSG V2.0 only provides a recommendation of using 35mm solid core doors to certain areas, which should achieve R_w30 , irrespective of the partition ACI rating. However, it is well known that the larger the area of the door relative to the partition in which it is installed, the lower the ACI performance of the composite partition becomes. Figure 4 shows the composite ACI rating of a partition based on varying the area of various door within an R_w45 wall.

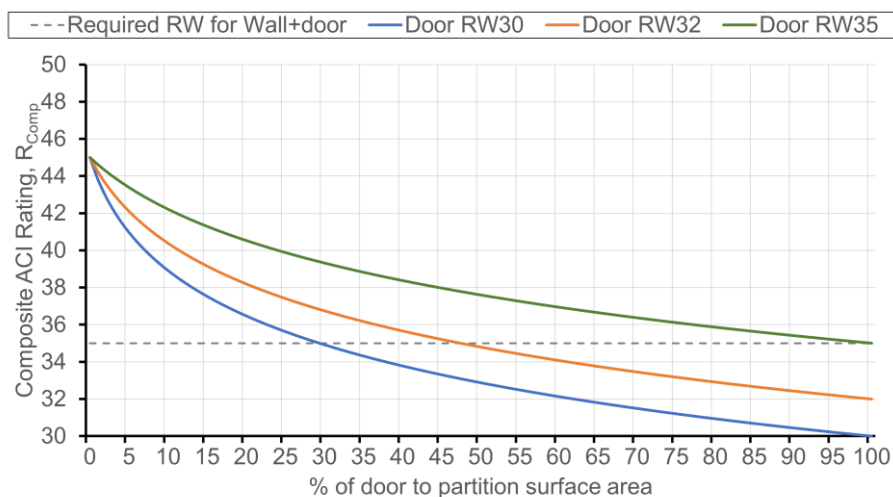


Figure 4 – Composite Acoustic Insulation rating of a partition with various doors with respect to the ratio of the door area to the wall area. An example of R_w45 wall + various door systems is shown.

The varying composite rating with respect to the surface area ratio implies a single value criterion for walls with doors is insufficient. The requirements for these wall and door systems should be discussed separately in the EFSG Acoustic Checklist.

Other elements such as operable walls, sliding doors, and accordion doors that are commonly included in the design of GLAs are missed in EFSG V2.0. Similarly composite rating for partitions with fixed windows is not mentioned. The NZ guideline provides requirements for ACI of connected spaces, which may be used as a helpful reference.

5.3 Speech Intelligibility

The SNR is influenced by INL, which includes both unoccupied internal noise and occupant-generated sounds. To enhance SI, it is crucial to minimise INLs, thereby improving the SNR. In GLAs, elevated INL can prompt teachers to raise their voices, a phenomenon known as the “Lombard effect”, to maintain SI. Providing a balanced set of criteria for INL and SNR can benefit the acoustic design for GLAs and other spaces where speech intelligibility is critical.

A survey of acoustic conditions in Primary School classrooms in Australia and other countries reported a comparison between the guidelines and measured data (Mealings, 2016). Comparing the survey results - i.e., the “OK” category as per (Mealings, 2016) - against EFSG, Table 2 provides an example of the potential minimum SNR which can be added to EFSG as a recommendation to achieve a compliant STI.

Table 2 - Comparison between different acoustic criteria from the EFSG Design Checklist compared against the survey of acoustic conditions for primary school classrooms (Mealings, 2016)

| Classrooms | Internal Noise Level Unoccupied (dBA) | | RT (s) | | SNR (+) | | STI | |
|------------------------------------|---------------------------------------|--------|--------|---------|--------------------------|--------|--------------------|-----------|
| | EFSG | Survey | EFSG | Survey | EFSG | Survey | EFSG | Survey |
| Overall | 35 | 30-40 | 0.5 | 0.4-0.6 | Recommended minimum 10dB | 10-15 | 0.60 (All GLAs) | 0.60-0.75 |
| Hearing/Language impaired children | 30 | 20-30 | 0.4 | 0.3-0.5 | | 15-20 | | 0.60-0.75 |
| 6-7 years | 35 | 28-35 | 0.5 | 0.4-0.6 | | 15-20 | | 0.70-0.75 |
| 8-9 years | | 35-40 | | 0.4-0.6 | | 12-18 | | 0.60-0.70 |
| 10-11 years | | 39-40 | | 0.4-0.6 | | 9-15 | | 0.60-0.61 |
| 12+ years | | 40-45 | | 0.4-0.6 | | 9-15 | | 0.60-0.61 |

5.4 Other issues

The following is a non-exhaustive list of potential improvements identified in the EFSG:

- RT and INL Criteria for GLAs:
 - Room volume: provide guidance on required acoustic treatment based on the volume of a space.
 - Form factor: The shape and dimensions of a room significantly influences sound propagation and reverberation, i.e., occurrence of fluttering echo.
 - Occupancy: provide guidance on INL and RT based on the intended number of occupants, e.g., lecture theatres or GLAs.
- INL Criteria for Naturally Ventilated Spaces:
 - Provide specific guidance for naturally ventilated spaces.
 - Developing criteria that balance acoustic comfort with sustainable ventilation strategies is crucial for energy-efficient designs.
- ACI for Operable Walls:
 - Provide guidance on ACI performance of operable walls used in flexible spaces, such as open-plan GLAs, meeting rooms, and examination halls, to address speech privacy and concentration.
 - Providing clear criteria to ensure a balance between reconfigurability and acoustic performance.
- Floor/Ceiling Design Recommendations for Impact Noise Control:
 - Provide guidance on designing floor/ceiling assemblies to mitigate impact noise transmission, particularly significant in multi-story educational buildings (vertical schools) where footfall noise and other impacts can be disruptive.
 - Providing specific design recommendations would help architects and engineers implement effective solutions for impact noise reduction, improving the overall acoustic environment.
- External noise impact - Traffic noise:
 - Provide guidance on typical building envelop façade and glazing requirements for development near busy roads or train rails.
 - Provide criteria for the overall noise level on the façade or glazing of different spaces from external noise sources.

6 CONCLUSION

From this comparative assessment, the key gaps in ESFG V2.0 were identified and discussed. The incompleteness of the acoustic criteria and design and construction recommendations for walls, doors, roof, ceiling, etc, is evident compared to other Australian and International guidelines. Following the AAAC or NZ guidelines, adding such recommendations for walls, doors, roof, ceilings, etc. can provide a baseline for design and construction and allow alterations to meet project specific targets while complying with the criteria. One main improvement can be about noise break-in including the rain noise criteria specific to the diverse weather conditions in NSW. Finally, the STI criteria can be corrected and clarified for different functions of educational spaces. With these improvements, EFSG has the potential to be a reference standard/guideline in Australia. A collaborative effort from consultants and authorities is required to significantly improve the existing version of the Acoustics EFSG beyond a Design Checklist.

ACKNOWLEDGEMENT

The authors would like to acknowledge the resources and support from the JHA Acoustic Group and Amy Martin. Special thanks to Daniel Castro from Volta Acoustics for his review.

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