Towards Climate-Responsive Acoustics: A Design Guideline Integrating Acoustic Best Practice with Environmental Considerations for Tropical Conference Centers

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ABSTRACT
Conference centers in tropical regions face a persistent design tension between the ventilation strategies required for thermal comfort and the acoustic isolation required for speech intelligibility. Acoustic design guidance for conference centers has been developed almost entirely within temperate contexts and transferred to tropical regions without adaptation. The transfer is unsound, because the environmental strategies on which tropical buildings depend; extensive natural ventilation, large openings, lightweight roofing and durable hard finishes are part of the strategies that degrade acoustic performance, while high humidity progressively reduces the effectiveness of the porous absorbers on which conventional acoustic remedies rely. Architects who design tropical conference centers consequently work without integrated guidance on how to reconcile two climatic performance requirements that conflict. This study develops an integrated, stage-based acoustic design guideline for conference centers in tropical climates, synthesized from a systematic literature review conducted in accordance with the PRISMA 2020 protocol. The synthesis draws together evidence on auditorium geometry and room proportioning, side- and rear-wall reflection control, the selection and performance of absorptive, diffusive and resonant acoustic materials, reverberation and sound-distribution targets, sound masking and intelligent acoustic systems, and digital acoustic simulation. These constituents are consolidated into a six-stage guideline spanning pre-design, architectural form, wall and ceiling treatment, material selection, environmental and mechanical integration, and acoustic systems and technology, supported by a summary framework table linking each stage to its key actions and evidence base. The guideline is intended as a practical, evidence-based reference for architects, acoustic consultants and engineers and facility planners engaged in the design of conference facilities in tropical region.
Keywords: *Conference center, architectural acoustics, soundscape, tropical architecture, sound absorption.*

1.0 INTRODUCTION
Effective acoustic design in conference centers is rarely the product of a single decision; it results from the coordinated interaction of room geometry, material selection, environmental strategy and, increasingly, digital design technology. In tropical regions (between the Tropic of Cancer and the Tropic of Capricorn), this coordination problem is intensified by a structural conflict between two environmental objectives. Natural ventilation, widely used in tropical architecture for energy and thermal-comfort reasons, requires openings; those same openings admit external noise from traffic, marketplaces and generators, raising background levels and reducing the signal-to-noise ratio on which intelligibility depends. High humidity, meanwhile, degrades the porous absorbers conventionally used to control reverberation, so the standard temperate remedy loses effectiveness in the very context where reverberation is most difficult to manage. The result is that architects in the tropical region face a trade-off rather than a technical deficiency, and the literature offers little guidance on how to negotiate it in large multipurpose spaces such as conference centers. This constitutes a clear research gap. While architectural acoustics and the design of performance spaces have been researched extensively, context-specific guidance for conference centers in tropical climates is largely absent.

Most existing standards and models spring from temperate regions and do not adequately account for high humidity, elevated temperatures, heavy rainfall and high background noise levels, nor for the widespread use of natural ventilation, lightweight materials and large openings. This research aims at developing a design guideline that integrates acoustic best practice with environmental considerations specific to tropical conditions, drawing on a systematic review of the architectural-acoustics and tropical-building-science literature. It addresses the gap through a single objective: to develop a design guideline integrating acoustic best practice with environmental responsiveness for conference centers in tropical climates. It answers the corresponding research question: What are the design guidelines to achieving quality acoustic environment in tropical conference centers? The contribution is procedural. Rather than proposing new acoustic principles, the study assembles established principles into a staged framework organized by the sequence in which design decisions become irreversible, and it treats climatic adaptation as internal to acoustic design rather than as a separate consideration. The article reviews the relevant literature and its limitations, presents the framework stage by stage with supporting parameters, discusses its coherence and the tensions within it and identifies its implications and limits.

2.0 LITERATURE REVIEW

Acoustic performance is an important component of conference center design because these facilities depend heavily on speech communication, presentations and interaction among large groups of users. Important acoustic parameters include reverberation time, sound pressure level, clarity and speech intelligibility (Long, 2014). Long's architectural acoustics specifically addresses the design of rooms for speech, multipurpose auditoria and related building-acoustic problems. Excessive reverberation and background noise can interfere with speech communication, whereas appropriately controlled reflections can contribute to effective sound transmission. Bradley et al. (2003), investigated the contribution of early reflections to speech communication and demonstrated their importance in rooms intended for speech.

Room geometry is also an important determinant of acoustic performance because the form and proportions of an enclosed space influence the distribution and reflection of sound. Okubo et al. (2001), using measurements in a multipurpose hall used for concerts, conventions and exhibitions, found that directional early-reflection parameters were sensitive to room shape, wall materials and seat position. Similarly, Zhao et al. (2015) investigated different room configurations and found that room shape and surface structures could affect reverberation time, sound-field distribution and speech transmission index in small meeting rooms. These findings indicate that room geometry should be considered together with functional requirements, surface treatments and seating arrangements from the early stages of conference center design.

Soundscape and Perceived Acoustic Quality

Conventional room acoustics primarily focuses on measurable physical characteristics of sound, whereas soundscape research introduces the perception and experience of users as important dimensions of acoustic quality. ISO 12913-1:2014 defines soundscape within a conceptual framework concerned with how people perceive and experience the acoustic environment in context. The standard also recognizes the relevance of soundscape principles to planning, design and management.

Kang and Schulte-Fortkamp (2016) further describe soundscape as an approach that combines physical acoustic conditions with human perception and the context in which sounds are experienced. Aletta et al. (2016) identify perceptual descriptors including pleasantness and eventfulness and demonstrate the importance of human perception in the assessment and design of acoustic environments. This perspective is relevant to conference centers because different spaces perform different acoustic and social functions. Main conference halls require acoustic conditions that support speech intelligibility and concentration, whereas foyers, circulation areas and social spaces may accommodate a more active acoustic environment. Consequently, acoustic quality should be considered in relation to the function, context and expected user experience of each space rather than being treated solely as a problem of noise reduction.

Acoustic Materials, Sound Absorption and Diffusion

Material selection is a fundamental consideration in conference center acoustics because surface properties determine how sound energy is absorbed, reflected or scattered within a space. Seddeq (2009) identifies material characteristics such as fiber type, thickness, density, airflow resistance and porosity as factors influencing sound absorption. Therefore, the selection and positioning of absorptive materials should correspond with the frequency characteristics of the room and the required acoustic performance. Sound diffusion provides another means of controlling reflected sound. Toyoda et al. (2009) investigated periodic diffusers for echo suppression and demonstrated the role of diffusive surfaces in controlling undesirable reflections. Kim et al. (2011) similarly examined diffuser application strategies in performance venues using scale models and reported differences in acoustic parameters according to hall shape and diffuser location. More recently, Jo and Jeon (2022) investigated diffusion using scale-model measurements and acoustic simulations and demonstrated that diffuser and reflector arrangements can influence parameters including reverberation time, early decay time, clarity and center time. These studies indicate that diffusion can be incorporated with absorption and reflection as part of an integrated strategy for controlling sound distribution.

The development of sustainable acoustic materials has also received increasing attention. D'Alessandro and Pispola (2005) investigated the sound absorption characteristics of sustainable fibrous materials and reported their potential as alternatives to conventional materials. Mamtaz et al. (2016) reviewed natural-fiber composites for acoustic absorption and identified factors including fiber characteristics, flow resistivity, thickness and material composition as important to acoustic performance. The authors also identified moisture resistance and antifungal performance as important limitations of some natural-fiber materials. Asdrubali et al. (2015) reviewed unconventional sustainable building insulation materials, while Jang (2023) reviewed sound-absorbing properties of a range of green materials derived from agricultural and plant-based resources. Such materials may therefore provide opportunities for tropical conference centers, although their acoustic performance must be considered together with moisture resistance, durability and environmental suitability.

Influence of Tropical Climatic and Environmental Conditions

The tropical environment introduces additional considerations because climatic conditions can influence sound propagation and because strategies used to achieve thermal comfort can create acoustic challenges. Gomez-Agustina et al. (2014) investigated the effects of air temperature and humidity on acoustic design and demonstrated that atmospheric attenuation can become significant, particularly at higher frequencies relevant to speech intelligibility. This is particularly relevant to large conference spaces where sound may travel considerable distances between a speech source and listeners. Natural ventilation represents another important consideration in tropical buildings. Although ventilation openings can contribute to thermal comfort and reduce dependence on mechanical cooling, they may also provide pathways for external noise. De Salis et al. (2002) examined noise-control strategies for naturally ventilated buildings and identified the conflict between the large openings required for airflow and the acoustic separation required to limit external noise intrusion. Barclay et al. (2012) similarly examined the interaction between environmental noise exposure and natural-ventilation potential in non-domestic buildings.

De Araújo and Bistafa (2012) further investigated façade elements designed to provide natural ventilation while maintaining sound insulation. Their study, undertaken in a hot and humid climate, demonstrated the difficulty of achieving sound insulation through façades containing openings, particularly at low frequencies, while also showing that appropriate configurations can provide both ventilation and improved acoustic performance. Bajraktari et al. (2015) likewise investigated sound insulation of double façades with openings for natural ventilation, highlighting the acoustic implications of ventilation openings in building façades. Rainfall is an additional environmental consideration in tropical regions. Idris et al. (2012) investigated noise generated when rainfall strikes uninsulated metal-deck roofing and reported that rain noise can interfere with occupants' activities. For conference centers, this finding indicates the importance of considering roof construction, ceiling systems and roof-space treatment as components of the acoustic envelope, particularly where lightweight metal roofing is used.

Environmental Noise, Natural Ventilation and Acoustic Technologies

Environmental and building-generated noise can significantly affect the acoustic performance of conference facilities. In Nigeria, Giwa et al. (2019) investigated noise and emissions from off-grid diesel-powered generators and measured generator-related noise from a sample of 105 generators in Ogun State. The findings demonstrate the relevance of generator noise within the Nigerian built environment. For conference centers, the location of generators and other mechanical equipment should therefore be considered during site planning and building zoning, with appropriate separation and noise-control measures provided for acoustically sensitive spaces. Computer-based acoustic modelling also provides an opportunity to evaluate acoustic conditions during the design process. Savioja and Svensson (2015) reviewed geometrical room-acoustic modelling techniques and noted their application to the prediction of sound propagation, including specular and diffuse reflections and diffraction.

Vorländer (2020) further presents auralization as a technique through which predicted acoustic conditions can be reproduced as sound, allowing aspects of the expected acoustic environment to be evaluated before construction. These approaches can assist designers in evaluating room geometry, surface treatments and acoustic performance during the design stage rather than relying entirely on post-construction correction. Emerging acoustic materials and structures also provide additional possibilities for sound control. Yang et al. (2020), reviewed acoustic metamaterials designed for sound absorption and discussed their ability to manipulate sound using engineered structures. Such technologies represent an emerging area of architectural acoustics, although their application in large conference facilities and tropical building environments requires further investigation regarding practicality, durability, cost and integration with conventional architectural systems.

3.0 METHODOLOGY

Research Design

The guideline synthesized in this study rests entirely on secondary data and technical materials rather than primary sources, this research therefore adopts a qualitative research design built around a systematic literature review (SLR). *Petticrew and Roberts* (2006) define a Systematic Literature Review as a structured process of locating, evaluating and synthesizing research findings to answer a specific research question, and this structure was followed to ensure that the guideline could be traced transparently back to its underlying evidence base. The review additionally followed the evidence-synthesis guidance of *Kitchenham and Charters* (2007) and was reported in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework (Page et al., 2021), selected specifically for the transparency and replicability it affords a design-oriented review of this kind. Fig 3.1 presents the PRISMA flow diagram of the study.

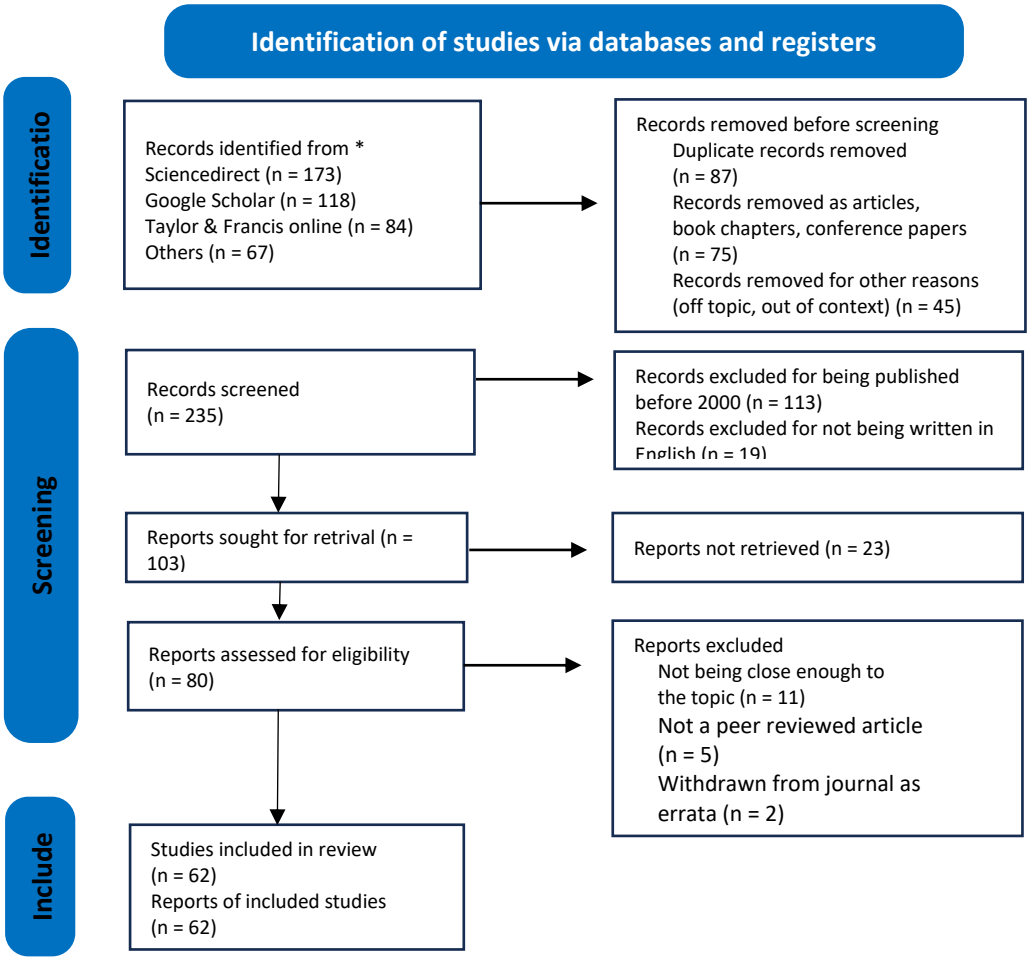


Fig. 3.1: A PRISMA 2020 flow diagram showing the Study's Selection Process.
Source: Authors' Researchwork 2026

Data Sources and Search Strategy

Literature was retrieved from ScienceDirect, Scopus, SpringerLink, Taylor & Francis Online and Google Scholar, selected as the databases with the strongest coverage of architectural acoustics and building-science publishing. Searches combined terms including "acoustic design", "architectural acoustics", "conference center acoustics", "auditorium design", "room geometry" and "acoustic simulation" using Boolean operators (AND, OR) to capture relevant combinations of these concepts. The search was restricted primarily to literature published between 2000 and 2026 to preserve contemporary relevance, although a small number of seminal, still-cited works falling outside this window principally foundational treatments of room and auditorium acoustics were retained where their theoretical contribution remained current in more recent scholarship. Only English-language publications were retained, and grey literature such as theses and industry design guidance was included alongside peer-reviewed material where it offered practical design detail not otherwise available in the academic record.

Screening and Study Selection

Study selection followed the four-stage PRISMA 2020 process of identification, screening, eligibility assessment and inclusion (Page et al., 2021). At identification, a total of 442 items were first found across the databases listed above and imported into a reference-management system to support de-duplication. At screening, titles and abstracts were assessed for relevance to architectural acoustics, room geometry, acoustic materials or acoustic technology as applied to conference, auditorium or comparable assembly-space design, 120 unrelated records outside this scope were removed. After removal of 87 duplicates, 235 distinct articles were left. At the eligibility stage, the full text of each remaining record was assessed against the inclusion and exclusion criteria and records that did not meet these criteria were excluded. Ultimately, 62 surviving records formed the evidence base synthesized into the guideline presented in this article, drawn from the broader systematic review of acoustic considerations for tropical conference center design.

Selection Criteria

Inclusion criteria:

1. Literatures published in English, between 2000 and 2026 with limited exceptions for seminal, still-cited foundational works.
2. Offers empirical evidence or theoretical insight relevant to auditorium, conference-center or comparable assembly-space acoustics.
3. Addresses room geometry, acoustic materials, sound masking or intelligent acoustic systems, or acoustic simulation and modelling.

Exclusion criteria:

1. Published in a language other than English, full text not accessible for review and opinion-based, anecdotal or non-peer-reviewed content lacking methodological rigor.

Data Extraction and Thematic Synthesis

A homogenous data-extraction approach was applied to each included study, capturing authorship, publication year, study context, research objective, acoustic parameter(s) examined, methodology and principal findings, consistent with the structured extraction approach described by Petticrew and Roberts (2006). Each study was then coded thematically according to the design dimension it primarily addressed; room geometry and auditorium typology, acoustic material performance, reverberation and sound distribution, sound masking and intelligent systems, or digital simulation and auralisation and these themes were consolidated into the six-stage guideline presented in Section 5. Only studies offering credible, contextually relevant design insight were carried forward into direct synthesis; weaker or tangential studies were either excluded or referenced only cautiously in supporting discussion.

Validity, Reliability and Ethical Considerations

To strengthen validity, priority was given to peer-reviewed journal articles and recognized technical references, supplemented selectively by grey literature offering practical design detail not otherwise available in the academic record. Reliability was supported through cross-verification of extracted content against the original source material for each study cited in the guideline. Because the review relies solely on secondary, publicly available material, no institutional ethical clearance was required; standard research-integrity practice was nonetheless followed throughout, including full and accurate attribution of every source consulted and avoidance of any claim not directly supported by the reviewed literature.

4.0 DATA PRESENTATION AND DISCUSSION

Architectural Form and Auditorium Geometry

The shape, size and proportioning of a conference hall have a direct bearing on how sound is reflected and distributed within it. Because speech-oriented spaces require shorter reverberation times than spaces intended for music, room size and form must be matched to the primary communicative function of the hall (Alagbe & Dimkpa, 2023). Parallel hard walls can cause sound waves to reflect repeatedly between surfaces, producing resonance and amplification at specific frequencies, whereas curved or irregular wall geometries diffuse sound, reduce echo formation and improve the uniformity of sound distribution across the audience (Mba, Okere & Ikpendu, 2025).

Among the principal auditorium typologies, the fan-shaped layout widens progressively from the stage toward the rear, with side walls splayed outward to increase seating capacity while preserving frontal sightlines. Bright, Daibi-Oruene, Imaah and Moses (2021) identify the fan-shaped form as the most widely used auditorium layout because it accommodates large audiences while maintaining a frontal orientation toward the speaker. Prodec Group (2026) recommends a length-to-width ratio between 1.2:1 and 2:1 for such spaces, in order to avoid the standing-wave problems associated with perfectly square proportions. Kamisiński (2010) notes that although sound reflected from the rear wall of a fan-shaped hall may reach the front seats with a noticeable delay, the splayed side walls themselves generally prevent the flutter echo that can occur between parallel surfaces, provided the rear wall receives appropriate absorptive or diffusive treatment. Kim, Kim and Jeon (2011), comparing scale models of fan-shaped and shoebox halls, found that the same diffuser placement produced markedly different effects on sound-pressure-level distribution depending on room geometry, underscoring that acoustic treatment decisions cannot be transferred directly between auditorium typologies. Zhao, Qiu, Cheng, Burnett, Williams, Burry and Burry (2015) further demonstrate that room shape alone can significantly affect reverberation time even when volume, surface area and absorption coefficients are held constant, confirming that geometric decisions carry acoustic consequences independent of material specification.

The rectangular, or shoebox, layout is one of the most acoustically predictable room geometries, characterized by parallel walls, a flat floor and a comparatively high ceiling (Lokki, Pätynen, Kuusinen & Tervo, 2016). Its principal acoustic advantage lies in the availability of side walls capable of generating useful lateral reflections

that reinforce the direct sound and contribute to a more spatially even sound field. However, this same parallelism can produce repeated reflections and flutter echo where surfaces are left hard and untreated, meaning that the shoebox form should not be regarded as inherently acoustically satisfactory without deliberate surface treatment. The horseshoe or U-shaped layout, by contrast, surrounds the stage on three sides and typically incorporates multiple balconies; Kamisiński (2010) states that the resulting abundance of reflecting and dispersing surfaces can help conceal minor acoustic defects, but Long (2014) cautions that multiple reflections arriving after the critical early-reflection period can interfere with speech clarity and, in some cases, produce audible echo. Balcony overhangs in horseshoe layouts also create shadow zones of reduced direct sound, a further factor that limits the suitability of this typology for speech-focused conference use relative to simpler geometries.

Vineyard-style layouts, which place the audience in tiered blocks surrounding a central performance area, offer strong sightlines but are associated with acoustic deficiencies including inconsistent balance between different seating sectors and reversed orientation of reflected sound (Harris, 2019); combined with the high cost and complexity of this typology, it is generally less suited to conventional conference center use than fan-shaped or shoebox alternatives. Room proportioning decisions extend to ceiling height and seating configuration. Prodec Group (2026) recommends ceiling heights that scale with room volume: approximately 2.7 - 3.5 m for small spaces below 200 m^3, 3.5 - 5.0 m for medium rooms of 200–1,000 m^3, and 5.0–8.0 m for halls exceeding 1,000 m^3, on the basis that excessively low ceilings restrict acoustic treatment options while unnecessarily high ceilings prolong reverberation time. The same source recommends raised or tiered seating so that each row has an unobstructed sightline over the row in front, reducing the amount of direct sound absorbed by intervening audience members before it reaches listeners further back.

Wall Treatment for Early Reflections and Echo Control

Side and rear walls play distinct acoustic roles in a conference hall. Bradley, Sato and Picard (2003) demonstrate that early reflections sound arriving at a listener shortly after the direct signal can significantly improve speech intelligibility, particularly where direct sound levels are otherwise reduced, provided that reflecting surfaces are configured to integrate with rather than compete against the direct signal. Side walls that are perfectly parallel and highly reflective risk producing flutter echo, while excessively angled walls may direct useful sound energy away from the audience; a moderate, alternating combination of reflective and diffusive treatment is therefore generally preferable to either extreme. The rear wall, positioned opposite the primary sound source, requires particular care because a hard, flat surface in this location can generate a delayed reflection perceptible as an echo. Rather than making the rear wall uniformly absorptive which risks producing an acoustically flat or lifeless space; a balanced combination of absorption and diffusion, calibrated to the distance between source and rear wall, is generally the more effective approach.

Acoustic Material Selection and Performance

Acoustic materials perform several distinct functions within a conference hall: absorption reduces reflected acoustic energy, reflection redistributes useful early sound energy, diffusion scatters sound to reduce localised concentration, and insulation limits the transmission of airborne sound between adjoining spaces. Chen, Hu, Cao, Huang, Wu, Lü and Peng (2019) describe how sound-absorbing materials dissipate acoustic energy through thermal-viscous effects at structure medium interfaces, while Huang, Li, Zhu and Tsai (2023) note that ongoing materials research has produced porous absorbers with improved durability, efficiency and fire resistance alongside resonant absorbers capable of targeting specific low- and mid-frequency ranges. Among porous absorbers including mineral wool, glass wool, fabrics and carpets, absorption efficiency is closely tied to material thickness, density and porosity (Kuttruff, 2017). Seddeq (2009), found that material thickness is strongly correlated with absorption performance at low-to-mid frequencies (100 - 2000 Hz) but has little effect above this range, a finding corroborated by Azkorra, Perez, Coma, Cabeza, Bures, Alvaro, Erkoreka and Urrestarazu (2015), Adnan and Rus (2013) and Mat Hassan and Rus (2013), each of whom recorded measurable improvements in absorption coefficient with increasing sample thickness across a range of biopolymer and composite materials. Soltani and Zerrebini (2012), Bilova and Lumitzer (2011) and Amares, Sujatmika, Hong, Durairaj and Hamid (2017) similarly link porosity and pore-channel configuration to absorption performance, noting that open, continuous pore networks generally outperform closed or restricted structures. Wertel (2000) reaches a consistent conclusion from testing of foam-based absorbers.

Beyond porous absorption, resonant absorbers comprising membrane resonators and Helmholtz (cavity) resonators provide a distinct mechanism for targeting specific, typically low-frequency, problem ranges, since their absorption performance depends on the resonant properties of the assembly rather than the porosity of the material itself (Cox & D'Antonio, 2004). Reflective surfaces, by contrast, are hard, smooth and non-porous, and are used deliberately where redistribution rather than absorption of sound energy is required, while diffusers scatter reflected sound into weaker, more evenly distributed components, reducing flutter echo and excessive

energy concentration at specific points in a hall. Audience seating and occupants themselves constitute a substantial and variable source of absorption, particularly at mid and high frequencies; Summers (2003) notes that changes in occupancy can meaningfully affect the reverberation characteristics of a hall, a consideration of particular relevance to conference centers, which may operate across a wide range of occupancy levels. Finally, sound insulation, the capacity of building elements to limit noise transmission between spaces should be specified as a distinct requirement from internal absorption and diffusion, since a well-treated interior does not compensate for poor insulation against external or adjoining-space noise (Ogolodom, Lawson & Amakiri, 2025).

Reverberation Time and Sound Distribution

Reverberation time remains one of the most widely used metrics for evaluating the acoustic quality of an enclosed space, describing how long sound persists after the source has stopped (Inomaye & Daminabo, 2021). For conference and general-purpose auditoria intended to support both speech and occasional musical use, a reverberation time of approximately 1.5 - 2.5 seconds is generally recommended, with a working target of around 2.0 seconds for medium-sized, general-purpose spaces (Alagbe & Dimkpa, 2023; Oniku & Bello, 2011). Because speech intelligibility depends on the reflected sound not overlapping excessively with the direct signal, conference halls should generally be designed toward the shorter end of this range relative to spaces used primarily for music (Gramez & Boubenider, 2017). Sound distribution, the average spread of sound energy across the audience area depends heavily on how wall and ceiling surfaces reflect incident sound, since enclosed reflecting surfaces behave, geometrically, in the same manner as mirrors reflect light (Gou & Lau, 2017); uneven distribution of reflective and absorptive treatment can therefore produce inconsistent listening conditions across different seating zones even where the overall reverberation time is within target.

Sound Masking and Intelligent Acoustic Systems

Sound masking, the deliberate introduction of a low-level, unobtrusive background sound to reduce the intelligibility of unwanted or distracting noise offers a complementary strategy to passive absorption and insulation, particularly where speech privacy between adjoining spaces is required (Gelfand, 2010; Mallat, 2009). The technique operates by reducing the signal-to-noise ratio between a source of unwanted speech and an unintended listener, thereby lowering the intelligibility of overheard conversation, and has been shown to be effective in open-plan and adjoining-room settings where poor acoustic separation would otherwise compromise speech privacy (Hongisto, Varjo, Leppamaki, Oliva & Hyona, 2016; International Organization for Standardization, 2008; Golmohammadi, Aliabadi & Nezami, 2017; Wu & Zhao, 2024). Martin and Liebl (2017) caution, however, that the effectiveness of sound masking depends heavily on careful installation and on user acceptance of the masking signal, meaning that masking should be treated as a calibrated design element rather than a generic background addition. Sound-masking systems typically comprise ceiling- or surface-mounted loudspeakers or vibration transducers, digital signal generators and zone controllers, and, in more advanced installations, ambient sound-level sensors capable of adjusting the masking level automatically as background noise fluctuates a capability of particular relevance in tropical conference centers, where traffic, rainfall and HVAC operation can cause background noise levels to vary considerably over the course of a single event.

Digital Simulation and Predictive Design Tools

A recurring theme across the reviewed literature is the value of predictive acoustic simulation in resolving design trade-offs before construction. Savioja and Svensson (2015), reviewing geometrical room-acoustic modelling techniques, describe how established simulation platforms allow designers to predict room-acoustic performance using geometric acoustics, ray tracing and image-source modelling, enabling comparison of alternative room geometries and treatments prior to construction. Vorländer (2020) extends this discussion through auralization the conversion of simulated acoustic data into audible sound which allows designers, clients and building owners to experience a proposed acoustic environment directly, improving communication between architects and acoustic consultants during the design process. For tropical applications specifically, this simulation capability allows moisture-resistant material alternatives to be compared against conventional options within the same virtual model, supporting material decisions that account for long-term climatic exposure rather than laboratory-only performance data (Long, 2014).

5.0 PROPOSED DESIGN GUIDELINE

Drawing on the evidence synthesized above, the following six-stage guideline is proposed for the acoustic design of conference centers in tropical regions, moving sequentially from initial site assessment through to the deployment of acoustic technology.

Pre-Design Stage

1. Conduct a site noise survey, accounting for tropical urban noise sources such as traffic and generator use, prior to site selection or confirmation.
2. Evaluate site-specific climatic data, including temperature, humidity, prevailing wind and seasonal rainfall patterns.
3. Determine ventilation strategy (natural, mechanical or hybrid) early, recognizing its direct implications for acoustic isolation.
4. Establish target reverberation time (generally 1.5 - 2.5 seconds for general-purpose conference use) and speech-intelligibility criteria appropriate to the intended function of the space.

Architectural Form Stage

1. Favour fan-shaped or shoebox auditorium layouts over horseshoe or vineyard configurations for speech-focused conference use, based on their more predictable acoustic behavior.
2. Maintain a length-to-width ratio of approximately 1.2:1 to 2:1 to avoid standing-wave effects associated with square proportions.
3. Set ceiling height according to room volume, and design a raked or tiered seating configuration to preserve sightlines and reduce audience-body absorption of direct sound.
4. Avoid perfectly parallel, untreated hard surfaces that increase the risk of flutter echo.

Wall and Ceiling Treatment Stage

1. Configure side walls to generate controlled early reflections, using moderate wall alignment combined with alternating reflective and diffusive surfaces.
2. Apply absorptive or diffusive treatment to the rear wall in proportion to the distance from the sound source, to prevent delayed reflections perceived as echo.
3. Zone the ceiling into a moderately reflective front section (above the speaker), a mixed absorptive/diffusive mid-section, and a strongly absorptive rear section to control long-delay reflections.

Material Selection Stage

1. Specify porous absorbers (mineral wool, glass wool, fabric and carpet systems) for mid-to-high-frequency control, selecting thickness, density and porosity according to the target frequency range.
2. Specify membrane or Helmholtz resonators where low-frequency control is required, recognizing that resonant absorbers perform differently from porous absorbers and should be positioned accordingly.
3. Balance absorptive and diffusive treatments deliberately rather than relying on absorption alone, to avoid producing an acoustically "dead" space.
4. Account for audience occupancy variation when specifying seating absorption, since reverberation characteristics can shift meaningfully between full and partially occupied conditions.
5. Prioritize moisture- and humidity-resistant acoustic finishes given the demonstrated vulnerability of conventional porous absorbers to tropical climatic exposure.
6. Specify sound insulation as a distinct requirement from internal absorption and diffusion, addressing transmission from external and adjoining spaces.

Environmental and Mechanical Integration Stage

1. Treat ventilation openings as an acoustic design element, not solely a thermal one, given the documented conflict between natural ventilation and noise isolation.
2. Separate mechanical plant rooms (HVAC, generators) from occupied and acoustically sensitive spaces, and orient equipment-room doors away from critical listening areas.
3. Acoustically isolate and vibration-mount mechanical plant, including backup generators, from occupied spaces.

Acoustic Systems and Technology Stage

1. Where speech privacy between adjoining spaces is required, incorporate a calibrated sound-masking system rather than relying on passive insulation alone.
2. Consider ambient noise-level sensors for masking systems in tropical settings, given the potential for background noise to fluctuate with traffic, rainfall and HVAC cycling.
3. Employ digital acoustic simulation during design to test alternative geometries, materials and ventilation configurations against one another before construction.
4. Where feasible, use auralization to communicate expected acoustic outcomes to clients and design teams prior to construction.

Summary Framework

Table 1 consolidates the six design stages, their principal actions and the evidence base underpinning each, providing a single point of reference for applying the guideline within a conventional design workflow.

Table 1: Summary Framework of the Six-Stage Acoustic Design Guideline for Tropical Conference Centers.

Design Stage	Key Actions	Primary Evidence Base
Pre-Design	Site noise survey; climatic data review (temperature, humidity, wind, rainfall); ventilation strategy decision; target RT and STI criteria set.	Feeley & Stroud (2018); Alagbe & Dimkpa (2023); Oniku & Bello (2011)
Architectural Form	Select auditorium typology (fan-shaped or shoebox preferred); control length-to-width ratio (1.2:1 - 2:1); set ceiling height by room volume; design sitting rake and sightlines.	Prodec Group (2026); Bright et al. (2021); Kim, Kim & Jeon (2011); Zhao et al. (2015); Lokki et al. (2016)
Wall and Ceiling Treatment	Configure side walls for controlled early reflections; apply strong absorption to rear wall; zone ceiling into reflective, mixed and absorptive bands.	Bradley, Sato & Picard (2003); Long (2014); Kamisiński (2010)
Material Selection	Specify porous, membrane and Helmholtz absorbers by frequency target; balance absorption with diffusion; select materials by thickness, density and porosity data; apply humidity-resistant finishes.	Cox & D'Antonio (2004); Chen et al. (2019); Huang et al. (2023); Seddeq (2009); Azkorra et al. (2015)
Environmental and Mechanical Integration	Treat ventilation openings acoustically; isolate HVAC and generator plant; separate mechanical rooms from occupied zones.	Ogolodom, Lawson & Amakiri (2025); Gramez & Boubenider (2017)
Acoustic Systems and Technology	Apply sound masking where speech privacy is required; run digital acoustic simulation across alternatives; use auralisation for stakeholder review.	Golmohammadi, Aliabadi & Nezami (2017); Savioja & Svensson (2015); Vorländer (2020)

Source: Authors' synthesis of the Reviewed Literature (2026)

6.0 CONTRIBUTION AND APPLICATION

The guideline presented here differs from conventional acoustic design references in two respects. First, it is organized explicitly around the sequence of decisions made during a tropical conference center project from site assessment through to technology deployment rather than around acoustic theory alone, making it directly usable within a normal design workflow. Second, it integrates climatic responsiveness as a first-order consideration at every stage, rather than treating tropical adaptation as a supplementary note appended to guidance developed for temperate conditions. By consolidating evidence on auditorium geometry, wall and ceiling treatment, material performance, environmental integration and acoustic technology into a single, sequential and evidence-referenced framework, the guideline offers architects and engineers working in tropical settings a practical starting point for reconciling acoustic performance with the thermal and environmental demands of the climate, addressing a gap noted throughout the reviewed literature regarding the scarcity of tropical-specific acoustic design guidance.

7.0 LIMITATIONS AND DIRECTIONS FOR FURTHER WORK

The framework proposed here is built entirely on secondary evidence rather than original field measurement, and its validity is therefore bound by the quality and scope of the underlying studies (Page et al., 2021). A substantial proportion of the evidence synthesized particularly on room geometry, material performance and sound masking originates from research conducted outside tropical settings, and while the underlying acoustic principles are not climate-dependent, their practical application under sustained tropical humidity, temperature and ventilation practice has not been extensively validated empirically. Future work should therefore prioritize field measurement

and post-occupancy evaluation of conference centers designed according to this or comparable guidance, in order to confirm that the reverberation, intelligibility and material-durability outcomes anticipated from the literature are in fact achieved under real tropical operating conditions.

8.0 CONCLUSION

Achieving good acoustic performance in tropical conference centers requires more than transplanting acoustic design conventions developed for temperate climates. The evidence reviewed here supports a structured, stage-based approach in which auditorium geometry, wall and ceiling treatment, material selection, environmental integration and acoustic technology are addressed jointly and from the earliest point in the design process, rather than as sequential or independent concerns. The six-stage guideline proposed in this article, together with its accompanying summary framework, offers architects, engineers and facility planners a practical starting point for this integrated approach, while underscoring the continued need for tropical-specific empirical research to validate and refine acoustic design recommendations under real climatic operating conditions.

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