



INFLUENCE OF MIHRAB GEOMETRY ON ACOUSTIC PERFORMANCE IN MALAYSIAN MOSQUES USING COMPUTER SIMULATION

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Abstract

Acoustic quality is essential in mosque architecture as it influences speech intelligibility and worshippers' auditory experience. Although the mihrab is a prominent architectural element, its contribution to the overall acoustic performance of mosques remains insufficiently understood. This study evaluates the influence of mihrab geometry on the acoustic performance of six Malaysian mosques using ODEON room acoustic simulation. Three acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), were analysed to compare different mihrab configurations. The findings reveal that variations in mihrab geometry have only a limited effect on acoustic performance, whereas prayer hall volume, ceiling configuration, and surface materials exert greater influence on speech intelligibility and sound distribution. The study highlights the importance of considering holistic architectural design strategies in mosque planning while preserving traditional mihrab forms. These findings provide practical guidance for architects, planners, and conservation practitioners in designing and conserving acoustically effective mosque environments.

Keywords: Mosque Architecture; Architectural Acoustics; Mihrab Geometry

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INTRODUCTION

Mosques have long served as the spiritual, cultural, and social centres of Muslim communities, providing spaces for congregational prayers, religious education, and community activities (Baydoun et al., 2025). Beyond their religious significance, mosque buildings represent complex architectural environments where spatial configuration, construction materials, and geometric forms collectively influence environmental performance, including thermal comfort, lighting, ventilation, and acoustics. Among these attributes, acoustic quality is particularly important because the primary functions of a mosque rely on the clear transmission of speech during daily prayers, Friday sermons (khutbah), religious lectures, and Qur'anic recitation (Abdou, 2003). Consequently, achieving good speech intelligibility while maintaining an appropriate reverberant environment has become a fundamental consideration in mosque design.

The acoustic environment of a mosque differs substantially from that of other public buildings due to its unique architectural characteristics and functional requirements. Unlike theatres or concert halls that are primarily designed for musical performances, mosques are intended to optimise speech intelligibility while simultaneously preserving an appropriate degree of reverberation that enhances the spiritual experience associated with Qur'anic recitation. Achieving this balance presents a significant architectural challenge, particularly in contemporary mosques where increasing prayer hall dimensions, higher ceiling volumes, large domes, and the extensive use of hard reflective materials frequently produce excessive reverberation and uneven sound distribution (Din et al., 2013; Syazana et al., 2021; Din & Anuar, 2019). Consequently, acoustic performance has become an increasingly important consideration in mosque design, particularly as architects seek to reconcile aesthetic expression with functional requirements.

Architectural acoustics has become an integral component of building performance evaluation because it directly affects occupant comfort, communication effectiveness, and the overall quality of indoor environments. Previous studies (Setiyowati et al., 2026; Nazli et al., 2017) have demonstrated that room geometry, enclosure volume, ceiling configuration, surface materials, and interior architectural elements significantly influence acoustic behaviour within enclosed spaces. In religious buildings, these factors determine how sound waves propagate, reflect, and decay throughout the prayer hall, thereby affecting important acoustic parameters for evaluating speech clarity and acoustic quality within worship spaces.

Among the architectural elements within a mosque, the mihrab occupies a unique functional and symbolic position. Located on the qiblah wall, it indicates the direction of prayer while serving as the location from which the imam leads congregational worship (Whelan, 1986). In Malaysian mosques,

mihrab designs vary considerably in terms of geometry, depth, curvature, and decorative treatment, reflecting differences in architectural styles and historical development (Rosniza, 2011). Traditionally, the concave form of the mihrab has been associated with favourable acoustic characteristics, as it is believed to enhance the projection of the imam's voice towards the congregation (Khidir, 1998; Ahmad et al., 2013; Hossameldien & Alshan, 2019). Nevertheless, empirical evidence regarding the extent of its contribution to the overall acoustic performance of mosque prayer halls remains limited.

Recent advances in computer-based acoustic simulation have enabled researchers to evaluate architectural acoustic performance under controlled conditions before construction or renovation (Abd Jalil et al., 2019). Despite increasing interest in mosque acoustics, most previous studies have examined the combined influence of room volume, ceiling configuration, dome geometry, and material properties, while comparatively few have isolated the effect of mihrab geometry under consistent architectural conditions (Nazli et al., 2017). Consequently, architects and conservation practitioners continue to have limited evidence on whether modifications to mihrab geometry significantly improve speech intelligibility or overall acoustic performance.

Therefore, this study investigates the influence of different mihrab geometries on the acoustic performance of six representative Malaysian mosques using computer simulation. The evaluation is based on three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT). The findings provide evidence-based insights into the acoustic role of mihrab geometry and support architects, planners, and conservation practitioners in balancing architectural authenticity with acoustic performance in the design and conservation of mosque prayer halls.

LITERATURE REVIEW

Mosque Architecture and Acoustic Performance

Mosques are among the most significant public buildings in Islamic societies, serving not only as places of worship but also as centres for education, social interaction, and community development (Rasdi & Tajuddin, 2007; Yusoff, 2026; Baydoun et al., 2025). Their architectural form has evolved across different regions in response to climatic, local traditions, technological advances, and cultural influences. Despite these regional variations, the principal function of the mosque remains unchanged: to provide an environment that facilitates congregational and effective communication between the imam and worshippers. Consequently, architectural design must satisfy both symbolic and functional requirements, including the provision of an acoustically comfortable environment.

Daily prayers, Friday sermons (khutbah), Qur'anic recitation, and religious lectures depend on the accurate transmission of spoken words throughout the prayer hall. Poor acoustic conditions may reduce speech clarity, diminish listener concentration, and affect worshippers' overall experience (Kusno et. al 2025). Therefore, acoustic performance should be considered an integral component of mosque design rather than a secondary engineering consideration. Architectural elements such as prayer hall dimensions, ceiling height, dome geometry, structural configuration, and material selection collectively influence sound propagation within mosque interiors. Large-enclosed volumes and highly reflective finishes, which are common in many contemporary mosques, often increase reverberation time and reduce speech intelligibility unless appropriate acoustic design strategies are incorporated. These observations demonstrate that architectural form and acoustic performance are closely interrelated and should be evaluated as complementary aspects of building design

Architectural Acoustics in Mosque Design

Architectural acoustics examines the interaction between sound and the built environment, emphasising how spatial configuration, enclosure geometry, and surface materials influence acoustic performance. In mosque architecture, acoustic quality is essential because speech intelligibility directly affects prayers, Qur'anic recitation, and religious sermons. Therefore, successful mosque design requires a balance between architectural aesthetics and functional acoustic performance. Three objective parameters are widely used to evaluate mosque acoustics: Sound Pressure Level (SPL), which measures sound distribution; Speech Transmission Index (STI), which assesses speech intelligibility; and Reverberation Time (RT), which indicates the persistence of sound after the source has ceased. Together, these parameters provide a comprehensive assessment of acoustic performance and are widely employed in both field measurements and computer-based acoustic simulations.

Previous studies (Nazli et al., 2017; Abdou, 2003; Eldien, 2024) have consistently shown that room volume, ceiling configuration, dome geometry, and surface finishes exert substantial influence on these acoustic indicators. Excessively long reverberation times may produce overlapping reflections that reduce speech clarity, whereas insufficient reverberation may diminish the perceived richness of Qur'anic recitation. Therefore, the challenge in mosque design is to achieve an appropriate balance between clarity and reverberance that supports both verbal communication and religious recitation

The Mihrab as an Architectural and Acoustic Element

The mihrab is one of the most recognisable architectural features in mosque design. Located on the qiblah wall, it identifies the direction of Makkah and provides the position from which the imam leads congregational prayers. Although its symbolic and religious significance has been extensively documented, its functional contribution to acoustic performance remains less clearly understood. Traditionally, many mosque builders have believed that the concave geometry of the mihrab assists in reflecting or projecting the imam's voice into the prayer hall. This assumption has influenced mosque architecture across different Islamic civilizations, resulting in diverse mihrab forms ranging from shallow recesses to deep semi-circular niches. Malaysian mosques similarly exhibit considerable diversity in mihrab geometry, reflecting differences in historical period, architectural style, and construction technology.

Numerous studies on mosque acoustics have primarily focused on the influence of prayer hall volume, ceiling configuration, dome geometry, building materials, and electroacoustic systems on overall acoustic performance. Comparatively, limited research has investigated the isolated influence of mihrab geometry under comparable architectural conditions. Recent advances in computer-based acoustic simulation, particularly using ODEON (Naylor & Rindel, 1992), have enabled reliable prediction of key acoustic parameters, including Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT). However, existing studies have largely adopted an engineering perspective, with limited emphasis on the implications of mihrab geometry for architectural design and heritage conservation. Therefore, this study addresses this research gap by evaluating the influence of different mihrab geometries on the acoustic performance of Malaysian mosques through computer simulation to support evidence-based mosque design and conservation.

RESEARCH METHODOLOGY

The first stage of this study involved the identification and selection of representative mosques in Malaysia for acoustic simulation. From the inventory of 56 mosques documented by Ahmad et al. (2013), six mosques were purposively selected as representative case studies for controlled computer-based acoustic simulation rather than as a statistically representative sample of all Malaysian mosques. The selection was guided by architectural diversity and the availability of sufficiently detailed architectural information for three-dimensional reconstruction. This selection enabled controlled comparison of alternative mihrab geometries across different architectural contexts while maintaining the modelling requirements necessary for reliable acoustic simulation and aimed to ensure that the chosen case studies reflected variations

in architectural characteristics that could potentially influence acoustic performance.

Several selection criteria were established to ensure the suitability of the case studies. These included roof typology, construction period (ranging from the 1800s to the 1900s), mihrab geometry, spatial configuration, and the availability of complete architectural drawings for three-dimensional modelling. In addition, mosque layout, prayer hall geometry, and other architectural features were considered to ensure that the selected mosques represented the evolution of Malaysian mosque architecture while providing sufficient variation for comparative analysis. The selected mosques encompass different architectural styles and historical periods, thereby allowing the influence of mihrab geometry on acoustic performance to be evaluated across diverse architectural contexts. The availability of accurate architectural drawings further enabled the development of reliable three-dimensional digital models for acoustic simulation.

Mosque Description

Table 1 summarises the principal physical and architectural characteristics of the six selected mosques used as case studies in this research. The information includes the year of construction, prayer hall volume, architectural style, and geographical location of each mosque. These characteristics were selected because they are recognised as important factors influencing the acoustic behaviour of enclosed worship spaces.

The six mosques, located across the western region of Peninsular Malaysia, represent a broad spectrum of Malaysian mosque architecture, encompassing both traditional and modern architectural styles constructed between the nineteenth and twentieth centuries. Their inclusion enables a comparative assessment of acoustic performance across different architectural periods and design typologies. Selected prayer halls exhibit considerable variation in spatial volume, ranging from approximately 617 m³ in smaller mosques to more than 2,500 m³ in larger prayer halls. This variation provides an appropriate basis for investigating the influence of mihrab geometry while accounting for differences in room size and spatial configuration. The diversity of architectural characteristics among the selected mosques enhances the robustness of the comparative analysis and allows the findings to be interpreted within a broader architectural context.

Table 1: Main physical characteristics of mosques adopted in the study

No	Mosque Name	Code	Volume (m ³)	Construction Year	Architectural Style
Pyramidal Roof Type					
1	Masjid Kg Bukit Belimbing	P1	617	1800s	Vernacular/Traditional
2	Masjid Jamek Kg Sungai Gulang-Gulang	P2	1109	1898	Vernacular/Traditional
3	Masjid Dato Dagang	P3	777	1876	Sino Eclectic
Dome Roof Type					
4	Masjid Sultan Suleiman	D1	1844	1932	Neo-Colonial
5	Masjid Jamek Kuala Lumpur	D2	2971	1909	Neo-Colonial
6	Masjid Sultan Alaeddin	D3	1030	1898	Neo-Colonial

Table 2: Basic information of simulation settings fixed in ODEON

No. of sound source	:	1 (set at 1.5 m high) setting at <i>imam</i> position
Sound source type	:	a) OMNI.S08 (0 gain) for RT b) BOSE BB93_NORMAL_NATURAL_S08 (Mihrab direction) Total power: 68.4 dB(A) for STI and SPL
No. of multi point source	:	Grid Points (all set at 1.5 m high)
		Pyramid Dome
		P1: 156 D1: 254
		P2: 295 D2: 493
		P3: 122 D3: 158
Impulse response length	:	between 1660 ms to 6020 ms
Temperature input	:	24°C
Background noise	:	NC-35
Scattering coefficient	:	0.05

Three-Dimensional Model Development and Acoustic Simulation

The three-dimensional (3D) models used for acoustic simulation were adapted from architectural models developed by undergraduate students as part of the Digital Architecture (DA) course. In this course, students reconstructed selected Malaysian mosques into detailed digital models based on existing two-dimensional (2D) architectural drawings. A total of six mosque models were selected and categorised into two principal architectural typologies based on their roof forms, namely pyramidal-type and dome-type mosques. Each category comprised three representative mosque models, enabling a comparative investigation of different architectural forms commonly found in Malaysian

mosque architecture. This classification facilitated the evaluation of whether roof typology, together with mihrab geometry, influences the acoustic behaviour of mosque prayer halls.

The present study focused exclusively on the main prayer hall of each mosque, as this space accommodates congregational prayers and contains the mihrab, which serves as the location from which the imam leads prayers and delivers sermons. Since the objective of the study was to investigate the influence of mihrab geometry on acoustic performance, other ancillary spaces such as corridors, ablution areas, offices, and circulation spaces were excluded from the simulation models.

A limitation of the study concerns the origin of the three-dimensional models, which were initially developed by undergraduate students based on available two-dimensional architectural drawings and subsequently refined for acoustic simulation. Although the principal spatial geometry was retained, insignificant architectural details, decorative elements, and non-essential surfaces were simplified or omitted to improve computational efficiency while maintaining the essential geometry of the prayer halls (Abd Jalil et al., 2019). Nevertheless, uncertainties may remain in the representation of complex architectural details, dimensions, surface conditions, and material properties, and these may influence the absolute acoustic values predicted by the simulations. Therefore, the results are interpreted primarily as comparative evidence of the relative influence of mihrab geometry rather than as exact representations of the measured acoustic performance of the existing mosques.

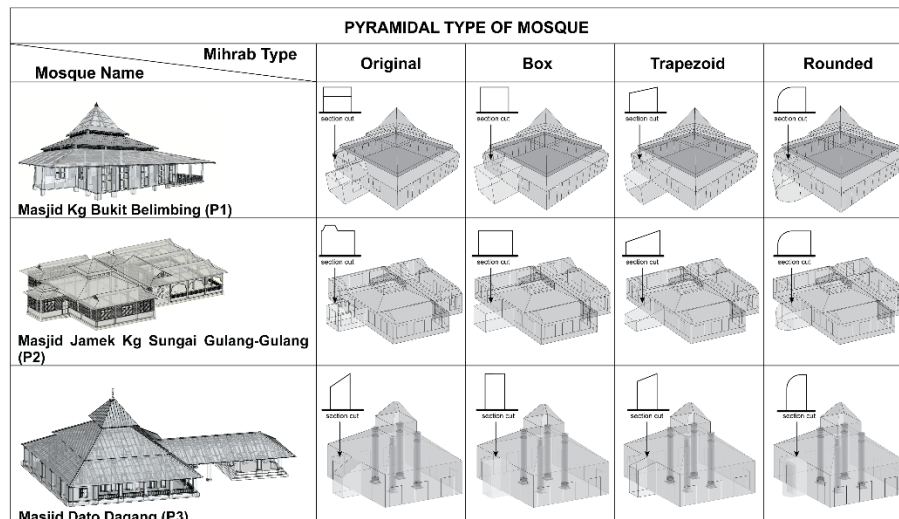


Figure 1: Type of mihrab for pyramidal type of mosque

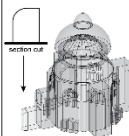
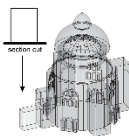
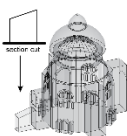
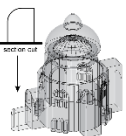
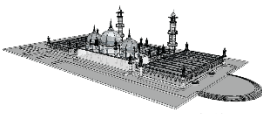
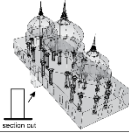
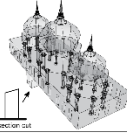
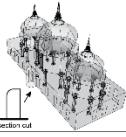
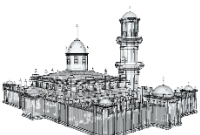
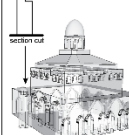
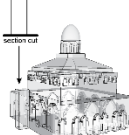
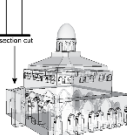
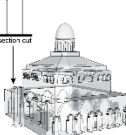
DOME TYPE OF MOSQUE					
Mosque Name	Mihrab Type	Original	Box	Trapezoid	Rounded
 Masjid Sultan Suleiman (D1)					
 Masjid Jamek Kuala Lumpur (D2)					
 Masjid Sultan Alaeddin (D3)					

Figure 2: Type of mihrab for dome type of mosque

Following model preparation, three prototype mihrab geometries representing commonly observed architectural forms in Malaysian mosques were digitally constructed and substituted into each prayer hall model. This approach enabled the acoustic influence of different mihrab configurations to be evaluated under identical architectural and environmental conditions while minimising the effects of other variables. The mihrab types of the representative mosques were identified with reference to the typological classification presented by Rosniza (2011), which served as the baseline for developing the simulation configurations. In this study, the semi-circular concaved mihrab type was represented by the rounded prototype. The recessed room on the qibla wall type was represented by two simplified geometric configurations according to the ceiling condition: box, representing a flat ceiling, and trapezoid, representing an inclined ceiling. These three configurations were therefore derived from the observed mihrab characteristics of the selected Malaysian mosques and translated into simplified geometric prototypes for controlled acoustic simulation. However, these configurations were not intended to constitute an exhaustive classification of Malaysian mihrab typologies, but rather to provide representative geometric prototypes derived from documented Malaysian mosque examples for the purpose of controlled comparative simulation.

All digital models were developed using SketchUp Pro® before being exported into ODEON Room Acoustic Software (Version 16) for acoustic simulation. Appropriate acoustic properties were assigned to all room surfaces based on their material characteristics. Material assignment represented one of

the most critical stages of the modelling process because the actual acoustic properties of existing mosque finishes were not always available. Consequently, sound absorption was selected from the ODEON material library and supplemented by published acoustic databases where necessary to ensure realistic representation of interior finishes as presented in Appendix A.

The sound source was positioned at the imam's standing location within the mihrab to replicate actual worship conditions. Receiver points were distributed throughout the main prayer hall according to its spatial configuration to evaluate sound propagation and speech intelligibility across the occupied prayer area. This arrangement enabled the comparison of three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), which collectively describe sound distribution, speech clarity, and reverberation characteristics within the prayer hall. Prior to the final simulations, a preliminary estimation of RT was performed to determine an appropriate impulse response length for each model. The selected impulse response length was configured to exceed two-thirds of the estimated reverberation time to ensure reliable acoustic calculations. The simulation settings and scattering coefficients adopted for each prayer hall are summarised in Table 2. In addition, the background noise level was standardised at 44 dBA (NC-35) based on average field measurements obtained from previous investigations (Nazli et al., 2017) to represent typical indoor acoustic conditions during congregational prayers. The completed digital models of the six mosque prayer halls together with the three prototype mihrab configurations are illustrated in Figures 1 and 2.

It should be noted that direct field validation of the simulation models was not undertaken because measured RT data for the six selected mosques were not available. The objective of the simulation was therefore comparative rather than predictive, focusing on the relative effect of alternative mihrab geometries on the overall reverberation characteristics of each prayer hall. To maintain comparability, the hall geometry, material assumptions, sound-source position, receiver distribution, and other simulation parameters were kept consistent when the three mihrab configurations were introduced. Consequently, the resulting RT differences were interpreted as the relative acoustic contribution of mihrab geometry under controlled simulation conditions. The absorption and scattering coefficients were assigned using the ODEON material library and published acoustic references where specific measured properties of existing finishes were unavailable. This limitation is acknowledged, as uncertainty in material acoustic properties may affect the absolute RT values predicted by the models.

ANALYSIS AND DISCUSSION

Sound Pressure Level (SPL) Distribution

Figure 3 illustrates the average A-weighted Sound Pressure Level (SPL) distribution with increasing source-to-receiver distance for the original and prototype mihrab configurations in both pyramidal- and dome-type mosques. Overall, all simulated prayer halls exhibited a similar attenuation pattern, whereby the SPL gradually decreased as the distance from the sound source increased. This trend is consistent with the expected reduction in sound energy as it propagates through enclosed spaces.

Among the pyramidal-type mosques, the SPL distributions generally followed comparable trends for all mihrab configurations. However, a noticeable deviation was observed in Mosque P2 (Figure 3b), where the original mihrab produced a maximum SPL difference of approximately 3 dB(A) compared with the three prototype geometries. Despite this localised variation, the overall sound attenuation pattern remained consistent across the different mihrab configurations. Similarly, the dome-type mosques (Figures 3c–3e) demonstrated comparable SPL distributions regardless of mihrab geometry. The maximum differences recorded among the dome-type models were generally less than 1.5 dB(A), indicating only minor variations in sound pressure distribution.

Overall, the simulation results suggest that changes in mihrab geometry produce relatively small variations in SPL distribution across both pyramidal- and dome-type mosques. Although isolated differences of up to 3 dB(A) were observed in individual cases, the overall sound pressure patterns remained largely unaffected by the different mihrab configurations.

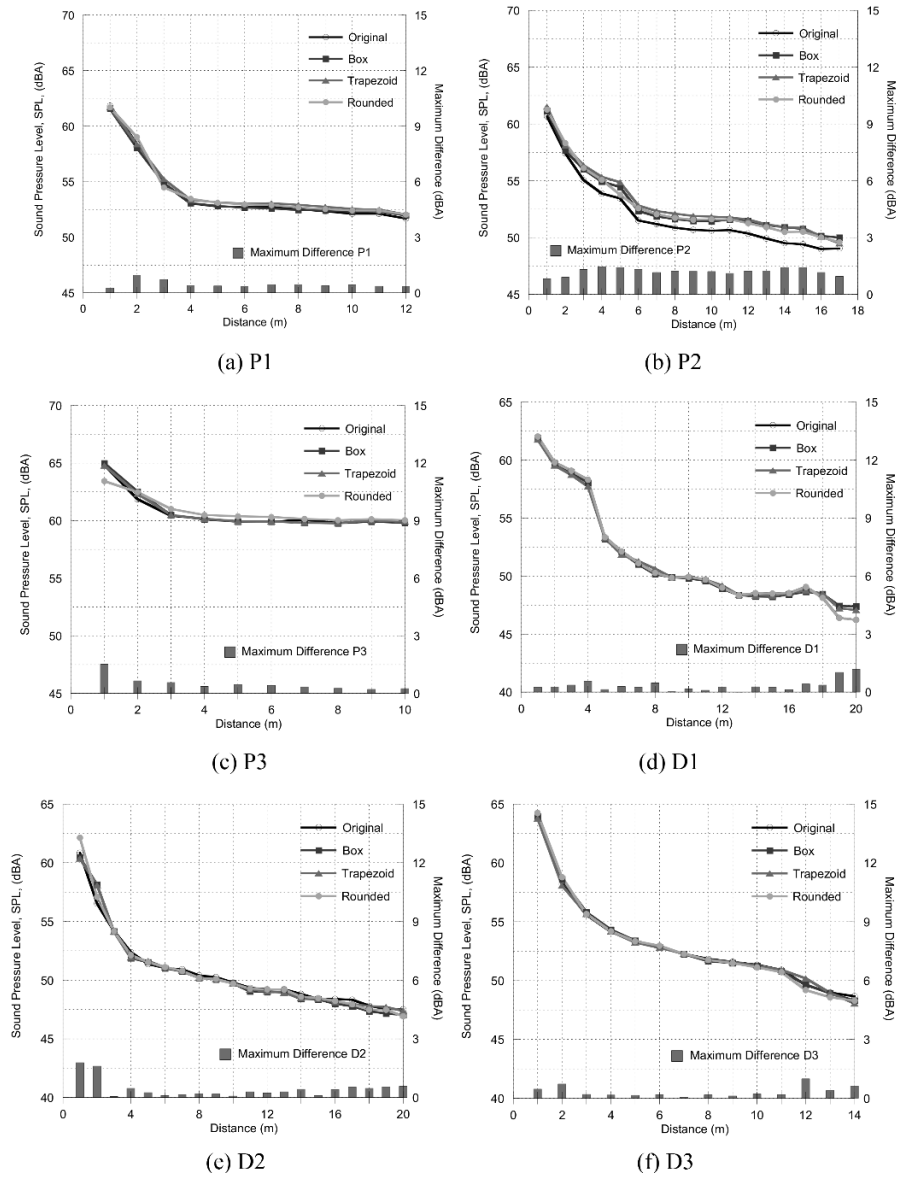


Figure 3: Comparison of sound pressure level (SPL) and maximum differences (MD) between each type of mihrab. Pyramidal Type (a) P1 (b) P2 (c) P3; Dome Type (d) D1, (e) D2 and (f) D3

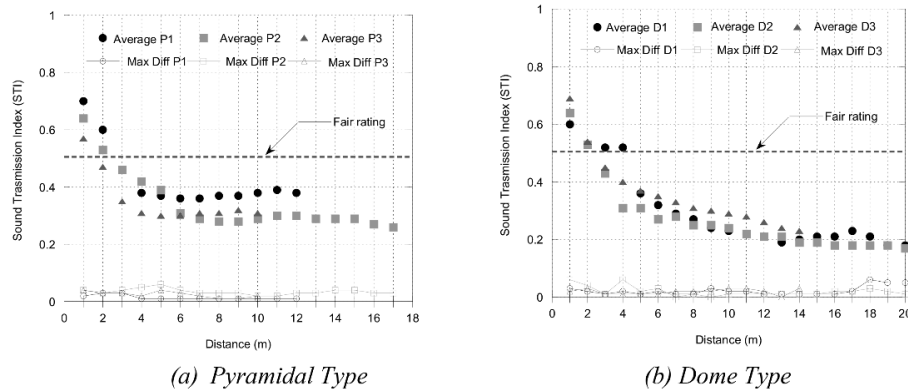


Figure 4: Comparison of average sound transmission index (STI) and maximum differences (MD) between all main prayer halls; (a) pyramidal type and (b) dome type

Sound Transmission Index (STI) vs Distance

Speech intelligibility is one of the most important acoustic performance criteria in mosque design, as it directly affects the clarity of prayers, Qur'anic recitation, and sermons. To facilitate a concise comparison among the different mihrab configurations, the STI values obtained from the simulations were averaged for each mosque, while the maximum differences between the original and prototype mihrab geometries were calculated to evaluate their acoustic influence.

Figure 4(a) and Figure 4(b) present the average STI values for the pyramidal- and dome-type mosques, respectively, as a function of the distance from the sound source. Overall, all simulated prayer halls exhibited a similar trend, whereby the STI gradually decreased with increasing source-to-receiver distance. This reduction indicates the expected deterioration in speech intelligibility as sound propagates further from the imam's position.

Among the six case study mosques, D1 consistently achieved the highest speech intelligibility, maintaining a 'Fair' or better STI rating over a larger portion of the prayer hall. In contrast, the remaining mosques exhibited STI values below the 'Fair' classification when the receiver distance exceeded approximately 2.0 m from the sound source.

Despite these variations among the individual mosque models, the maximum differences in STI between the original and prototype mihrab geometries were consistently less than 0.10. This finding indicates that modifications to mihrab geometry produced only marginal changes in speech intelligibility, regardless of roof typology or prayer hall volume.

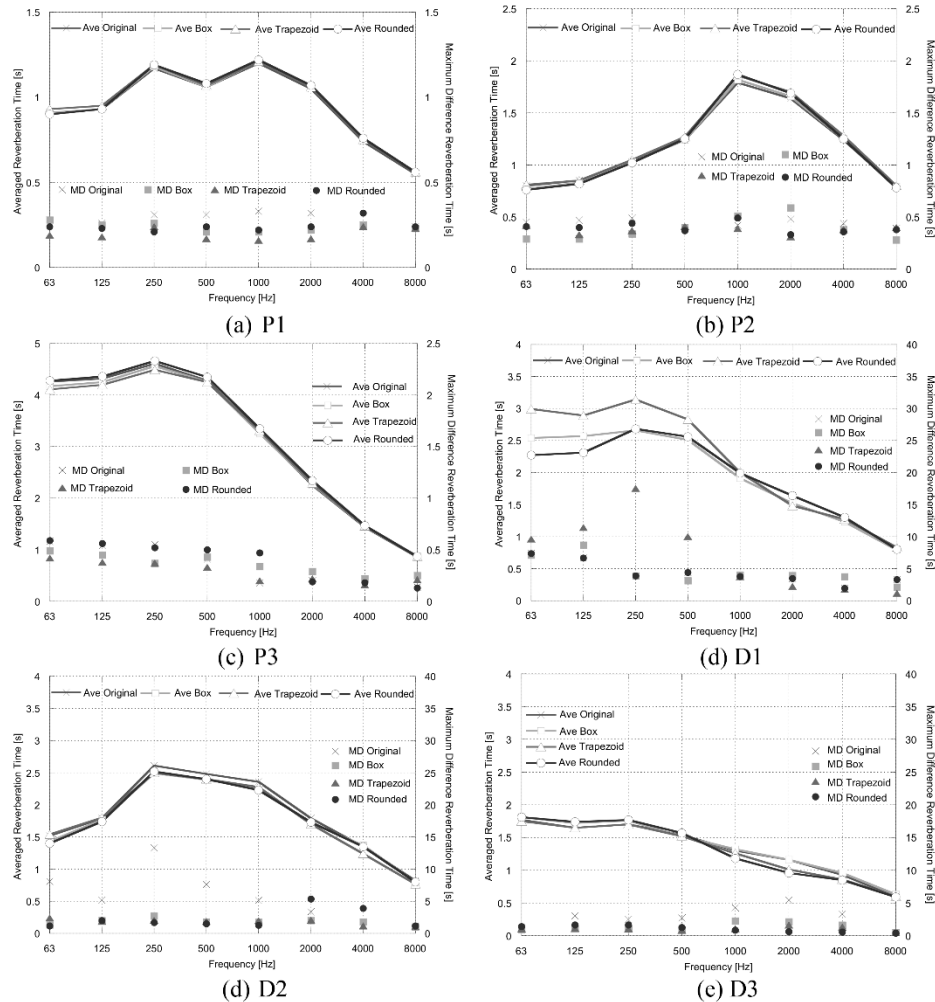


Figure 5: Comparison of averaged reverberation time (RT) between all types of mihrab. Pyramidal type (a) P1, (b) P2 and (c) P3; Dome type (d) D1, (e) D2 and (f) D3

Reverberation Time (RT)

Reverberation Time (RT) was evaluated to examine the acoustic response of the main prayer halls and to determine whether variations in mihrab geometry influence sound decay characteristics. Although reverberation is primarily governed by room volume, spatial geometry, and the acoustic properties of interior surfaces, RT was included in this study to evaluate the relative contribution of mihrab geometry under comparable simulation conditions.

The simulated $RT_{500\text{Hz}}$ values for the pyramidal-type mosques ranged from 1.06 s to 4.35 s, whereas the dome-type mosques recorded values between 1.52 s and 2.83 s. The RT values obtained at multiple receiver locations within each prayer hall were spatially averaged, and the maximum differences between the original and prototype mihrab geometries were calculated for comparative analysis, as presented in Figure 5. For the pyramidal-type mosques, Mosque P3 exhibited the highest average $RT_{500\text{Hz}}$ of approximately 4.0 s, reflecting its relatively large-enclosed volume and architectural configuration. Nevertheless, the spatially averaged RT values showed only minor variations among the different mihrab geometries across the analysed frequency range. The maximum differences were consistently below 0.6 s, indicating that changes in mihrab geometry had a negligible influence on the reverberation characteristics of the prayer halls.

A different trend was observed for the dome-type mosques. Slight discrepancies in the average RT values were identified, particularly for Mosque D1, where greater variations occurred at frequencies of 1,000 Hz and below. These differences may be associated with variations in room volume, dome configuration, and interior surface materials rather than the geometry of the mihrab itself. The simulated RT values fall within ranges reported in previous studies (Nazli et. al., 2017) of unoccupied Malaysian mosques of comparable size. These comparisons provide contextual reference for interpreting the simulated results; however, they do not constitute direct validation of the present models.

Overall, the results indicate that although reverberation characteristics vary among the selected mosques due to their architectural differences, modifications to mihrab geometry produced only marginal changes in RT. These findings suggest that reverberation performance is influenced more substantially by the overall spatial characteristics of the prayer hall than by the geometric configuration of the mihrab.

CONCLUSION

This study investigated the influence of mihrab geometry on the acoustic performance of six representative Malaysian mosques using ODEON room acoustic simulation. Three objective acoustic parameters, namely Sound Pressure Level (SPL), Speech Transmission Index (STI), and Reverberation Time (RT), were analysed to evaluate the acoustic response of different mihrab configurations under comparable architectural conditions. The findings indicate that mihrab geometry contributes to the acoustic behaviour of mosque prayer halls; however, its influence is dependent on the overall architectural context. While certain mihrab configurations may improve local sound reflection and speech intelligibility, particularly at shorter source-to-receiver distances and in

smaller prayer halls, their overall effect is moderated by broader architectural characteristics, including prayer hall volume, roof configuration, ceiling geometry, and surface material properties.

The findings provide practical implications for mosque design, conservation, and acoustic assessment. For architects, mihrab geometry should be considered as a complementary component of an integrated acoustic strategy, alongside prayer-hall volume, ceiling or dome configuration, room proportions, and surface materials, which have broader effects on sound propagation and reverberation. For conservation practitioners, the relatively limited acoustic influence of mihrab geometry suggests that traditional forms may generally be retained to preserve the historical and architectural character of mosques, while acoustic improvements can focus on appropriate spatial and material interventions. For acoustic consultants, assessment should consider the overall prayer-hall sound field rather than the mihrab as an isolated element, supported by computer simulation and, where possible, field measurements to inform design and conservation decisions. Future studies should combine computer simulation, field measurements, and user perception to develop comprehensive acoustic design guidelines for contemporary and heritage mosques.

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REFERENCES

- Abd Jalil, N. A., Din, N. C., Keumala, N., & Razak, A. S. (2019). Effect of model simplification through manual reduction in number of surfaces on room acoustics simulation. *Journal of Design and Built Environment*, 19(3), 31–41.
- Abdou, A. A. (2003). Measurement of acoustical characteristics of mosques in Saudi Arabia. *The Journal of the Acoustical Society of America*, 113(3), 1505–1517.
- Ahmad, A. A., Ali, A., Zin, M., & Arbi, E. (2013). Typology of interior architecture for traditional mosques in Peninsular Malaysia from 1700–1900 AD (Tipologi Seni Bina Masjid-Masjid Tradisional di Semenanjung Malaysia dari 1700–1900 Masihi). *Journal of Al-Tamaddun*, 8(2), 89–100.
- Ahmad, Y., Din, N. B. C., & Othman, R. (2013). Mihrab design and its basic acoustical characteristics of traditional vernacular mosques in Malaysia. *Journal of Building Performance*, 4(1).
- Baydoun, Z., Din, N. C., Iseric, T., Shukhratovna, M. D., & Shukhratovna, S. N. (2025). The role of mosques in sustainable communities: Bosnia and Malaysia compared. *Planning Malaysia*, 23.
- Din, N. C., & Anuar, A. S. (2019). Assessing the effect of dome shape and location on

- the acoustical performance of a mosque by using computer simulation. *International Journal of Automotive and Mechanical Engineering*, 16(1), 6415–6426.
- Din, N. C., Jalil, N. A., Ahmed, Y., Othman, R., & Otsuru, T. (2013, September). Measurement of the acoustical performance of traditional vernacular mosques in Malaysia. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings* (Vol. 247, No. 3, pp. 4289–4295). Institute of Noise Control Engineering.
- Eldien, H. H. (2023). Effect of dome-shape on the reverberation time of the mosque—A case study. *Civil Engineering and Architecture*, 11(4), 1749–1775.
- Eldien, H. H. (2024). Evaluation of the influence of mihrab shape on sound quality in mosques. *Journal of Engineering Research*, 13(3).
- Hossameldien, H., & Alshawan, A. A. (2019). Sound quality inside mosques: A case study on the impact of mihrab geometry. In *Indoor Environmental Quality*. IntechOpen.
- Khidir, O. M. (1998). *Bridging between the contemporary and the vernacular architecture* (Master's thesis, Virginia Polytechnic Institute and State University).
- Kusno, A., Din, N. C., Razali, A. W., Hamzah, B., Jamala, N., Mulyadi, R., & Kamil, K. (2025). Investigating the impact of environmental noise, humidity and surface treatment on mosque acoustic performance in Makassar, Indonesia. *Journal of Design and Built Environment*, 25(2), 40–56.
- Naylor, G., & Rindel, J. H. (1992). Predicting room acoustical behavior with the Odeon computer model. *The Journal of the Acoustical Society of America*, 92(4, Supplement), 2346–2346.
- Nazli, C. D., Adzahan, Z., Abdullah, Z., Harun, M., & Dimon, M. N. (2017). Acoustical performance of mosques: An overview of current research in Malaysia. In *ICSV24 Conference Proceedings* (pp. 4091–4097). International Institute of Sound & Vibration.
- Rasdi, M. T. M., & Tajuddin, M. (2007). Mosque architecture in Malaysia: Classification of styles and possible influence. *Journal Alam Bina*, 9(3), 1–37.
- Rosniza, O. (2011). *Mihrab design and ornamentation of selected mosques in Malaysia* (Doctoral dissertation, University of Malaya).
- Setiyowati, E., Ekasiwi, S. N. N., & Samodra, F. T. B. (2026). Comparative analysis of mosque acoustics quality in tropical and non-tropical climates: A literature review. *Journal of Islamic Architecture*, 9(1), 392–411.
- Syazana, W. P., Din, N. C., Yahya, M. N., Harun, Z., Yahya, K., & Junaid, T. (2023, May). The effect of diffusing acoustic panel on acoustical performance in a mosque with dome. In *11th International Conference on Mechanical and Manufacturing Engineering 2021 (ICME'21)* (Vol. 2530, No. 1, p. 070002). AIP Publishing LLC.
- Whelan, E. (1986). The origins of the Mihrāb Mujawwaf: A reinterpretation. *International Journal of Middle East Studies*, 18(2), 205–223.
- Yusoff, M. (2026). From worship to community hub: Exploring how mosque-based initiatives inspire tourism engagement. *Planning Malaysia*, 24(2).

APPENDIX A

Sound Absorption Coefficient Applied in This Study

Mosque	Architectural Element	Sound Absorption Coefficient							
		Frequencies. (Hz)							
		63	125	250	500	1000	2000	4000	8000
Masjid Kampung Belimbing (P1)	Ceiling	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11
	Door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10
	Floor	0.09	0.09	0.08	0.21	0.26	0.27	0.37	0.37
	Wall	0.28	0.28	0.22	0.17	0.09	0.1	0.11	0.11
	Window	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11
	Louvre	0.42	0.42	0.38	0.34	0.27	0.28	0.29	0.29
Masjid Jamek Kg. Sungai Gulang-Gulang (P2)	Ceiling	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11
	Door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10
	Floor	0.01	0.01	0.02	0.02	0.02	0.02	0.05	0.05
	Lower Wall	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
	Ventilation	0.42	0.42	0.38	0.34	0.27	0.28	0.29	0.29
	Wall	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11
Masjid Dato Dagang (P3)	Window	0.68	0.68	0.63	0.59	0.56	0.54	0.52	0.52
	Ceiling	0.05	0.05	0.05	0.05	0.08	0.14	0.20	0.20
	Column	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	Door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10
	Floor	0.01	0.01	0.01	0.02	0.02	0.02	0.05	0.05
	Wall	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Masjid Sultan Sulaiman (D1)	Floor	0.02	0.02	0.06	0.14	0.37	0.60	0.65	0.65
	Opening	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Inner Roof	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	Glass/Window	0.35	0.35	0.35	0.18	0.12	0.07	0.04	0.04
	Wall	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
Masjid Jamek Kuala Lumpur (D2)	Window Dome	0.35	0.35	0.25	0.18	0.12	0.07	0.04	0.04
	Column	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
	Floor	0.02	0.02	0.06	0.14	0.37	0.60	0.65	0.65
	Roof Structure	0.40	0.30	0.25	0.20	0.10	0.10	0.15	0.15
	Door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10
	Wall	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02
Masjid Sukltan Alaeddin (D3)	Window	0.35	0.28	0.25	0.17	0.12	0.07	0.04	0.04
	Ceiling	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11
	Floor	0.02	0.02	0.06	0.14	0.37	0.60	0.65	0.65
	Louvre	0.64	0.64	0.61	0.59	0.55	0.55	0.56	0.56
	Opening	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	Inner Roof	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
	Wall	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02

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