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The Effect of Mosque Acoustic Design and the Surrounding Environment on Prayer Health in Riyadh City Post-COVID-19

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Abstract

The Mosques in Saudi Arabia have recently witnessed a remarkable development in audio systems. However, residents complain about the high sound levels. This research aims to measure the sound level and study the factors that affect the noise in the interior and outdoor environment, health and management. The research utilizes a sound measuring device to determine inside and outside mosque noise, distribute a questionnaire to prayers at different times during the day, including at peak times. Three case studies in Riyadh. The result shows that the indoor sound level is above 60 ± 7 dB, which is within the limit. The maximum outdoor value exceeded the 68 ± 20 dB limit, and the minimum outdoor value was 58 ± 18 dB post-COVID-19. The research recommends reducing the level of noise The research results will be applied to manage sound levels inside the mosques using smart devices.

Keywords: data analysis acoustic design, mosque, interior space, surrounding outdoor environment, health and management

1. Introduction

Loud mosques reduce the ability to hear in the home because of distance. Most residents use mobile devices to track Azan's time. People who live near the mosques say that the loudspeaker affects their sleep during the day. This dilemma encouraged the researcher to investigate the problem. The literature was reviewed, and several research papers were found discussing the problem, including Makka and Al Haram mosques, as well as studies from Saudi Arabia, Malaysia, Egypt, and Turkia. International studies have indicated increased noise levels in urban societies from multiple sources significantly affecting human life. Noise sources include cars, trains, trucks, airports, mosques, daily human activities, construction activities, and industrial areas [1]. The noise level in the Al-Haram Al-Sharif Mosque in the Sahn area increased to more than 75% decibels, especially at peak times, such as the revival of Laylat al-Qadr on the 27th of Ramadan and the days of the Eids [2].

Three case studies in Al Rawdah, Riyadh, were selected. A survey was distributed to the prayers in three mosques and analyzed to identify the problem and suggest solutions.

1.1 Sound Characteristics

- Sound is transferred as waves. It reflects, transmits, and absorbs. Figure 1 shows a sound wave with a 100–1000 Hz frequency.

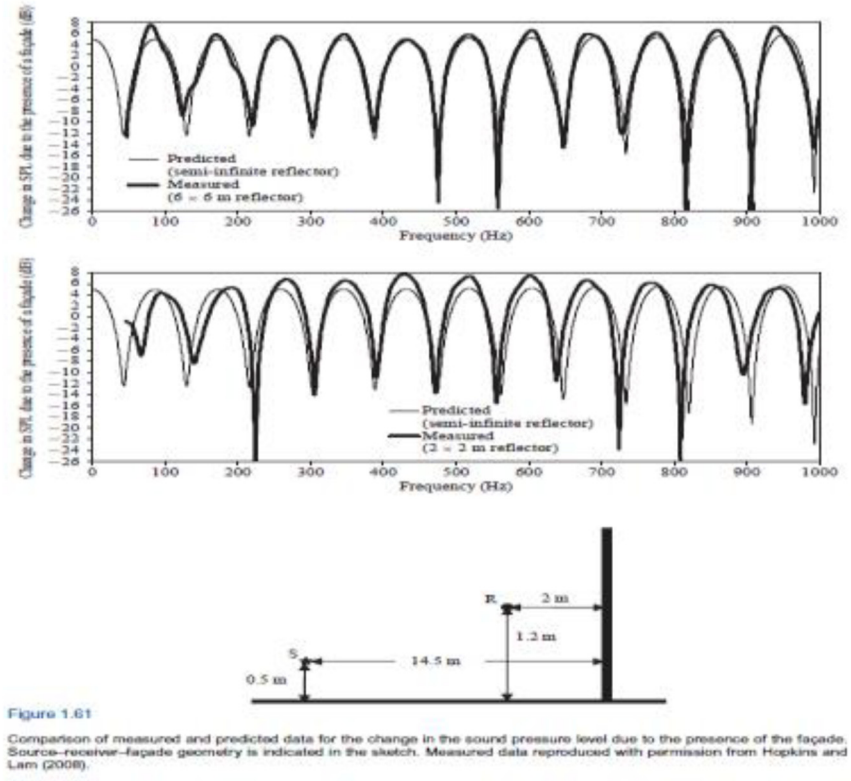


Figure 1. Sound wave with frequency 100-1000 Hz

- The measurement unit is Hz.
- Human hearing is in the range of 20–10000 decibel.
- In mosques, the accepted sound level is 35 HZ, a depth of 4 m, and a frequency of 40 Hz [3].

Figure 2 shows the absorption and reflection of sound from the façade.

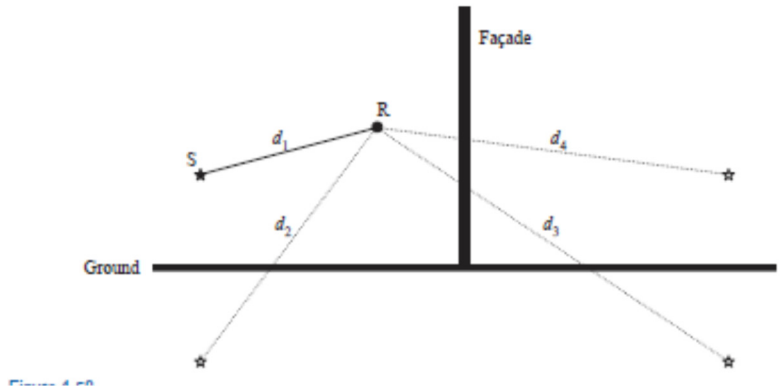


Figure 2. Absorption and reflection of sound from the façade

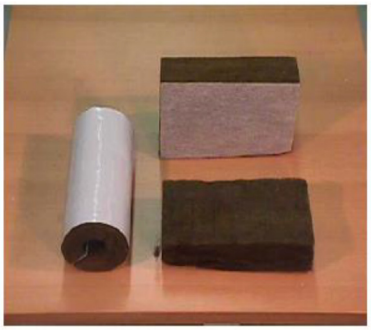
1.2 Factors Affecting the Characteristics of Sound

- Sound from the source.
- Distance between the source to the prayer.
- The solidity of wall and ceiling material.
- Absorption material [4].

1.3 Absorption Material

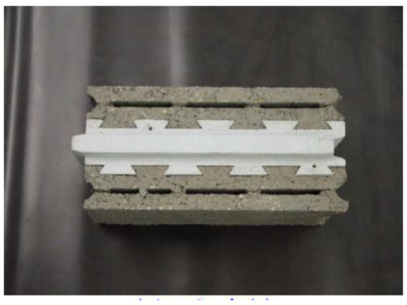
Absorption materials used in Riyadh city include Rockwool, concrete hollow blocks, thermal blocks, glass blocks, clay hollow blocks, and volcano cement blocks. Figure 3 shows the kinds of insulation materials in Riyadh.

Birlight insulation



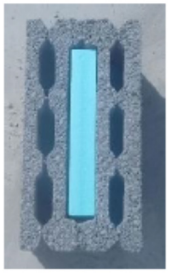
Gibson board insulation

Glass wool insulation



Cement Block

Clay hollow Bloch with insulation



Volcanoes cement block

Figure 3. Kind of insulation materials in Riyadh city. Source: [5]

1.4 Design of Space

Reference [6] highlighted the importance of studying the acoustic design in a mosque, including the space, material, and speech requirements. The research outcomes include more than one mosque to improve the results. In [7], they discussed the three main factors that affect acoustic design: space, material, and form. Meanwhile, three mosques in study [8] discussed the design and construction of mosques in Algeria and determined that they followed the international design without testing the acoustics. The result showed that indoor acoustics require review. In [9], the authors analyze Ali Paşa Mosque in Ankara by design style, speech transmission, and A-weighted sound levels. They found that the acoustics were probably considered in all design stages. Reference [10] asked why all the mosques in Saudi Arabia have a typical design. While the designer should study the impact of air conditioning, ceiling fans, and sound reinforcement systems, they also compared their results with other practices to determine the ideal acoustic value for mosques. Furthermore, [11] discussed sound levels in studio classes, measured sound levels during the day, and found that the sound level was 55 DC, which exceeds the limit.

In [12], the researcher discussed the importance of mosque building in the context of architectural design and cultural value. The study outlines that the designers need to analyze the Islamic activities in the mosque, typogram, and space. Furthermore, [13] highlighted the importance of the courtyard in daily mosque activities and its reflection into the acoustic system and encouraged using the courtyard system in mosque design. Meanwhile, [14] used an acoustic simulation of the different models generated from spatial configurations. It is possible to reconstruct old buildings with a sound system.

1.5 Noise Health Impact in Mosques Post-COVID-19

Reference [15] discussed the sound level inside and outside the mosque in Riyadh city compared with the sound level in mosques. The study found that noise caused hearing loss in some prayers. In [16], they studied traffic noise on human health during and after COVID-19; they found moderate noise levels in the urban area (50.9 ± 6.6 dB).

During the COVID-19 lockdown, mosques were closed for four months, then opened in August 2020. Thus, few prayers could pray at mosques [17]—50% of respondents prayed at home because of coronavirus fear.

1.6 Legislation

Reference [18] reported that Saudi Arabia's Islamic affairs minister is defending a contentious order restricting the volume of mosque loudspeakers, saying it was prompted by excessive noise complaints. The Islamic affairs ministry requested that speakers be set at no more than one-third of their maximum volume. Meanwhile, [19] discussed mosque construction in Sydney, stating it has a heavy construction approach. They report that designers should include social, cultural, and political aspects.

1.7 Objectives

1) Measure the sound level inside and outside mosques.

2) Study the space, material, and acoustic design.

3) Study its effect on human health post-COVID-19.

4) Suggest smart solutions and smart maintenance at the technical and design levels.

2. Methods

2.1 Sound Meter

We used a Sound Level Monitor Aid in Noise Compliance smart sound monitor. The sound data were analyzed with Microsoft Excel. Figure 4 shows the meter used to measure the sound level in the studio class. Figure 4. shows the sound level meter is used to measure the sound level in the studio class

	A sound level meter (or SPL) shows decibel values by measuring the environmental noise. Displays measure using dB values in various forms. You can experience tidy graphic design with a high frame by this smart sound meter.

Figure 4. The sound level meter is used to measure the sound level in the studio class. [20]

2.2 Distribution of the Survey and the Results

The survey was distributed to mosque prayers to determine their feelings regarding the sound level. The target was 100 respondents; only 20 respondents filled in the survey.

2.3 Statistical Analysis

We used SPSS statistical software to conduct one-sample t-tests for analyzing the data and measuring the mean values of the three case studies.

2.4 The Case Studies

The three case study mosques are located in one cluster in Al Rawdah 2, near Al Rawdah Park**.**

Figure 5 shows the three case study locations in Al Rouda 2, Riyadh City, Saudi Arabia.

Figure 5. The three-case study location in Al Rouda 2, Riyadh city

2.4.1 Case Study One

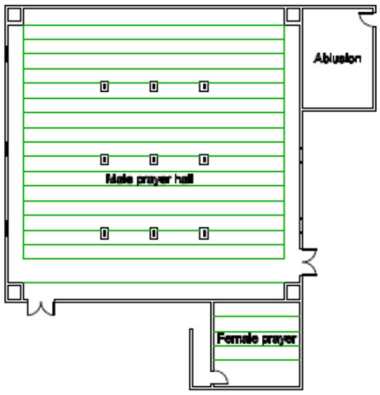
Madina Al Hujaj Mosque

The first mosque is in Al Rawdah 2 neighborhood, Al Rawdah Park. It is the largest mosque in the cluster. People pray there on Friday for Eid Al Fiter and Eid Al Adha.

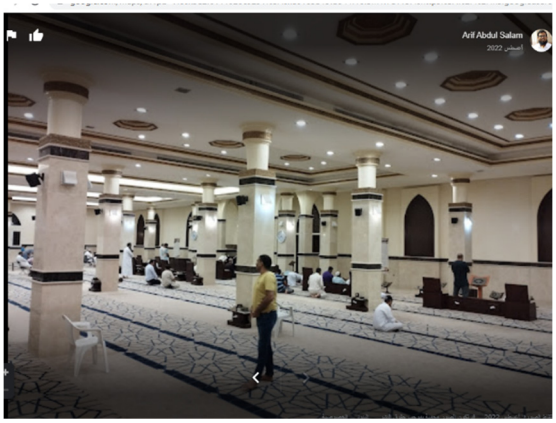
Figure 6 shows the location of case study one.

Figure 6. The location of case study one – Madina Al Hujaj Mosque, Al Rawdah 2 neighborhood, Al Rawdah Park

A. South elevation



B. Mosque plan



C. The interior space

D. East elevation

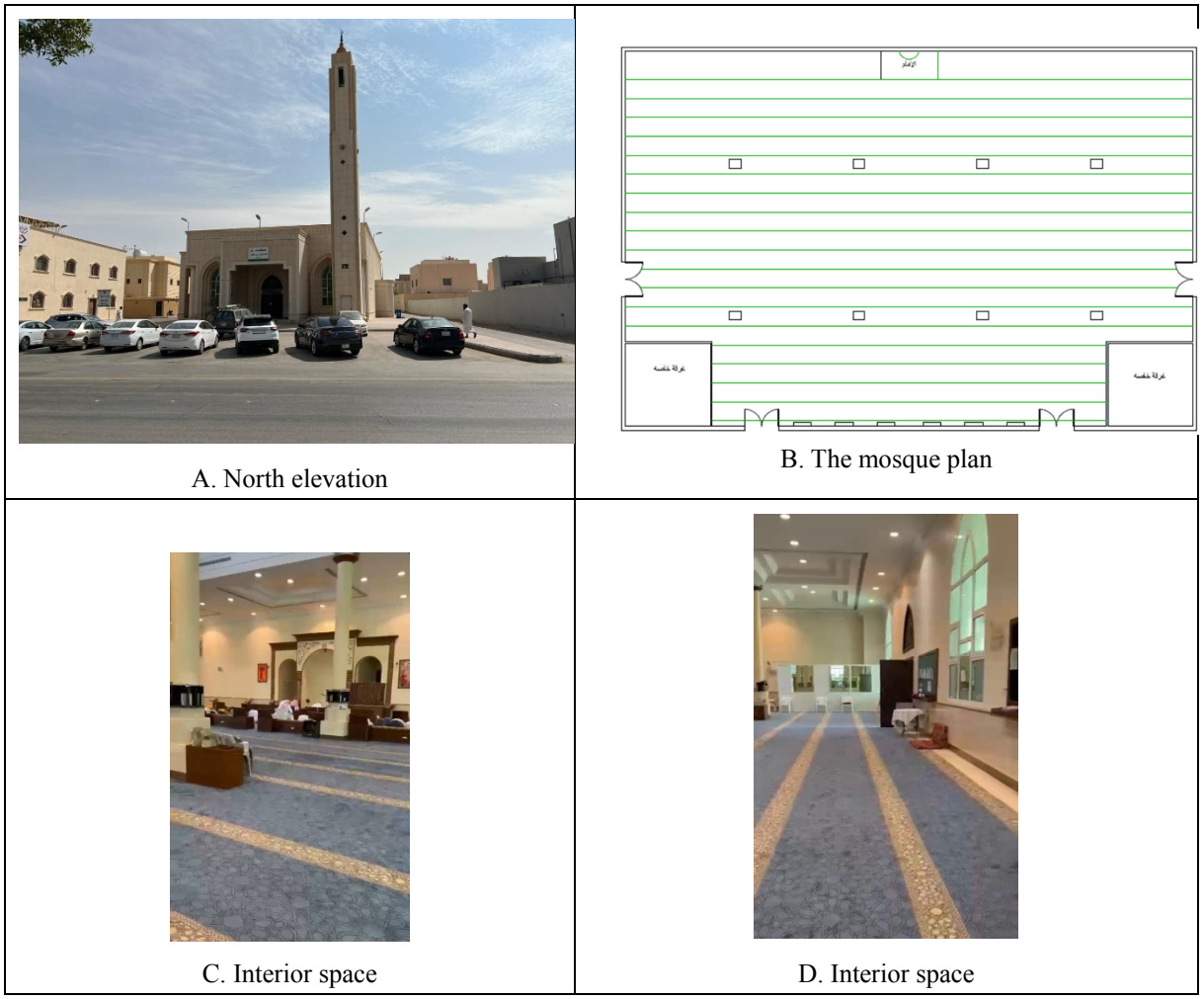
Figure 7. South elevation. B Mosque plan. C. The interior space. D. East elevation of case study one.

2.4.2 Case Study Two: Mouaya bin Sofyan Mosque

Figure 8. The location of case study two Mouaya bin Sofyan Mosque. This mosque is in the middle of the cluster. It is used in everyday prayers and during Ramadan.

Figure 8. The location of case study two. This mosque area is medium in the cluster. It is used in everyday prayers and during Ramadan

Figure 9. A: North elevation, B: mosque plan, C: interior space, D: interior space of case study two.



A. North elevation

B. The mosque plan

C. Interior space

D. Interior space

Figure 9. Shows A: North elevation, B: The mosque plan, C: interior space, D: interior space of case study two.

2.4.3 Case Study Three: Al Shekh Fraje Bin Shaker Mosque

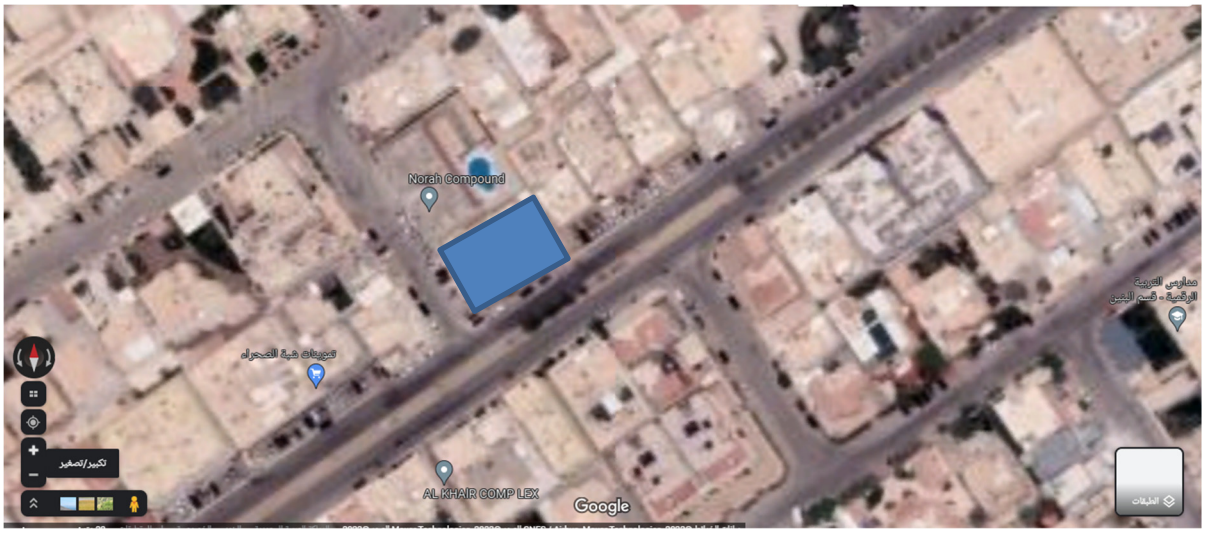
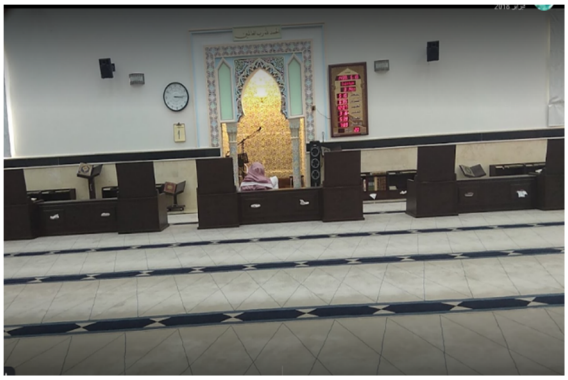
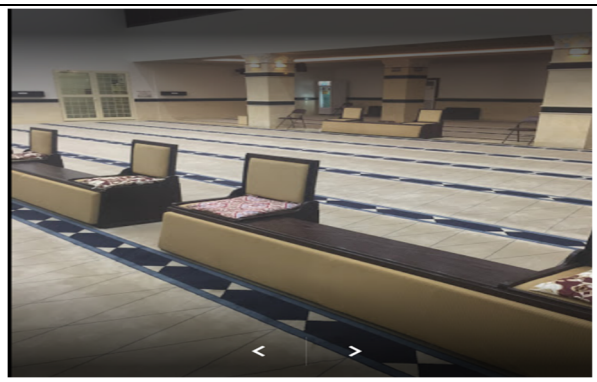


Figure 10. The location of case study three. The third mosque is located on Zaid Al Khair street, near Al Rawdah Park, in Al Rawdah neighborhood. It is the smallest mosque in this cluster. It is used in everyday prayers, and during Ramadan. It has two sections including both males and females.



A. The Interior space

B. West Elevation showing men entrance



C. The interior space showing the Mezzanine floor for women

D. The north elevation showing women entrance

Figure 11. A: Interior space, B: west elevation showing men's entrance, C: interior mezzanine.

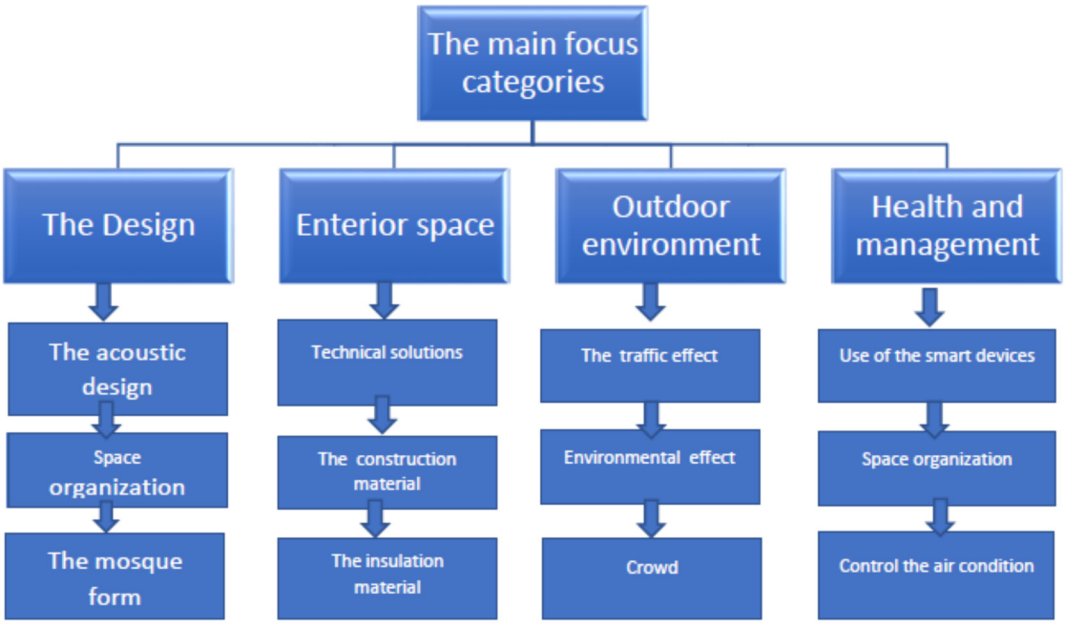


Figure 12. The categories of focus

2.5 Hypotheses

1) The high sound level in mosques is affecting human health post-COVID-19.

2) People are not able to hear the Azan at home.

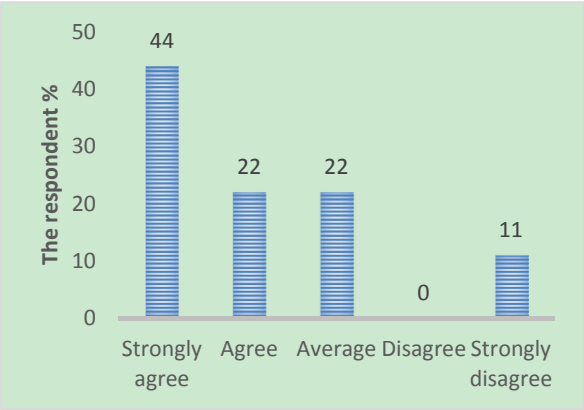
3) Acoustic design needs revision in the selected case studies.

3. Results

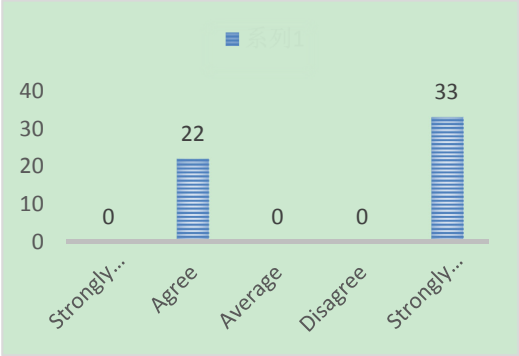
The survey was distributed on 14/9/2022. The target group was the prayers in Al Rawdah 2 neighborhood. The target sample size was 100 prayers. Only 20 respondents filled in the survey.

Table 1. The results of the survey

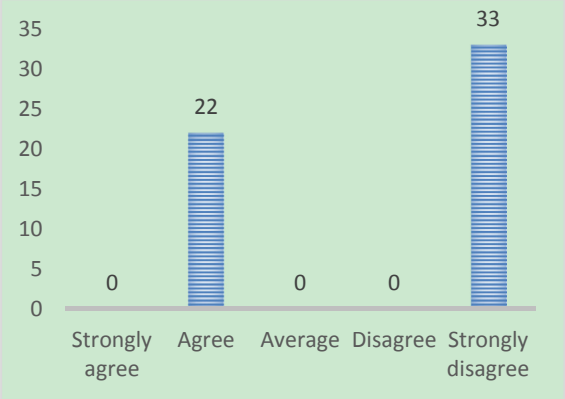
No.	Questions	Strongly agree	Agree	Average	Disagree	Strongly disagree	average results
1	Do you hear the Azan in your home?	44%	22%	22%	0	11	75%
2	Is the Azan very loud that is disturbing you from sleep?	0	22	0	0	33	45%
3	Is the khutbahs disturbing you at home?	0	22	0	33	44	46%
4	Is the Azan encouraging you to come to the mosque?	56	11	33	0	0	83%
5	Is the Azan helping you to wake up early in the morning and come to the mosque?	44	44	0	11	0	80%
6	Is the sound level inside the mosque high that disturbing you?	0	11	22	33	33	44%
7	Do the children in the mosques disturb you?	0	22	56	22	0	62%
8	Is the AC disturbing you inside the mosque?	0	22	11	22	44	48%
9	Do you think that crowdedness inside the mosque could increase the level of noise	11	33	0	22	33	60%
10	Do you think that cars in the outdoor environment could increase the level of noise?	**22**	**44**	**22**	**11**	**0**	78%
11	Do you think that it's important to hire child's keeper in mosques?	**33**	**33**	**22**	**11**	**0**	82%
12	Do you think it's important to classify the spaces into space for males, space for women and space for a Childers	**33**	**0**	**56**	**11**	**0**	60%
13	Do you think it's important to use insulation material to absorb the noise	**100**	**0**	**0**	**0**	**0**	Yes=17 NO=3
14	Do you think it's important to use heavy construction walls to minimize the level of noise	**44**	**0**	**33**	**11**	**11**	66%
15	Do you think it's important to use carpet to minimize the level of noise	**56**	**22**	**22**	**0**	**0**	78%
16	Do you think it's important to use smart devices to control the AC	**44**	**22**	**11**	**22**	**0**	74%



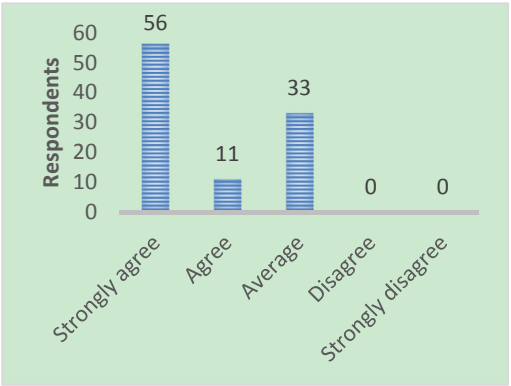
Q.1 Do you hear the Azan in your home?



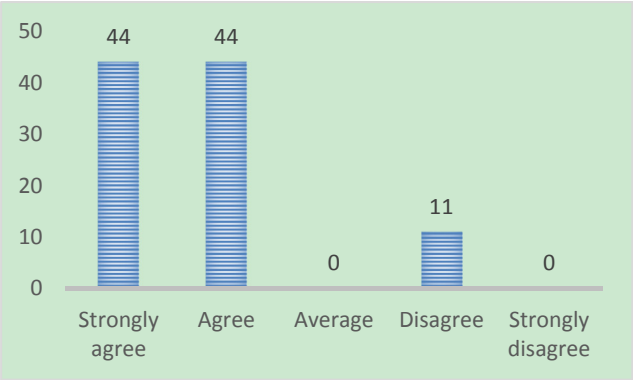
Q.2 Do the Azan is very loud that is disturbing you from sleep?



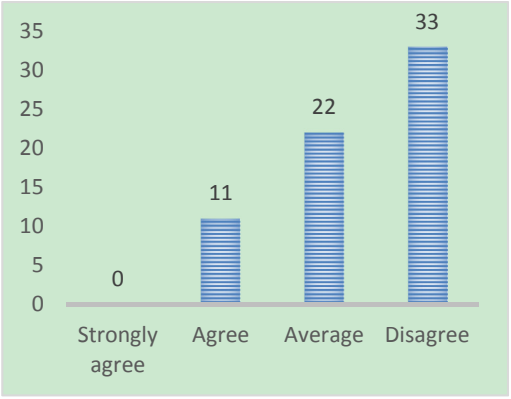
Q.3: Do the khotba is disturbing you at home?



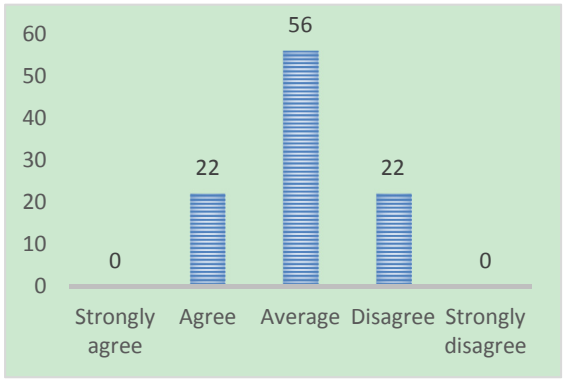
Q.4: Do the Azan is encouraging you to come to the mosque?



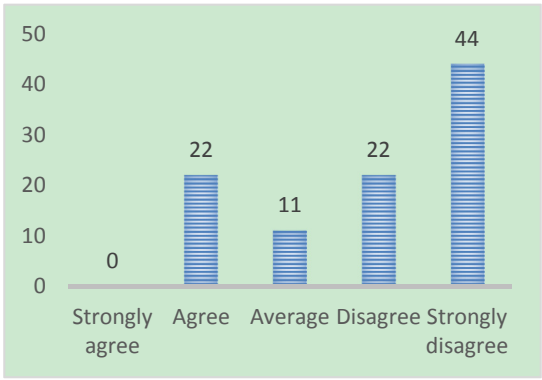
Q.5: Do the Azan is helping you to wake up early in the morning and come to the mosque?



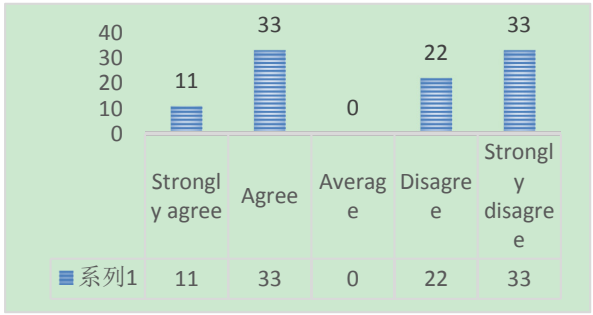
Q.6: Do the sound level inside the mosque is high that disturbing you?



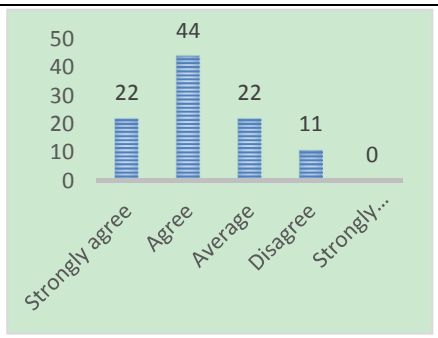
Q.7: Do the children in the mosques are disturbing you?



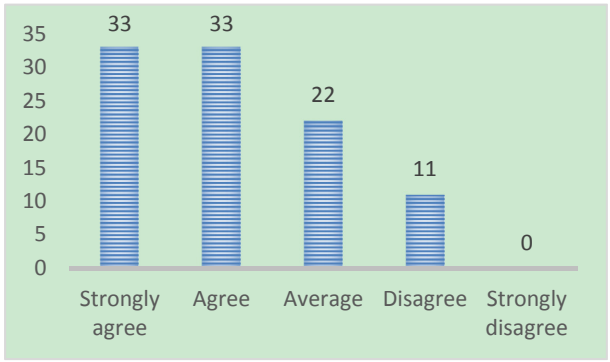
Q.8: Do the AC is disturbing you inside the mosque?



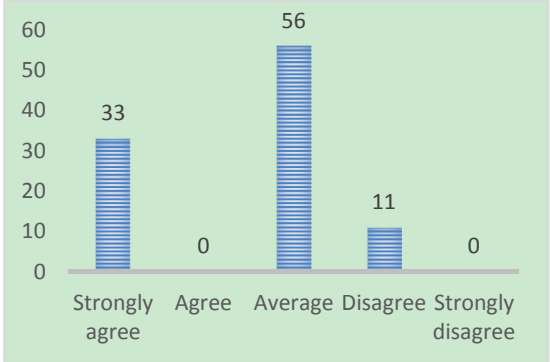
Q.9: Do you think that crowdedness inside the mosque could increase the level of noise



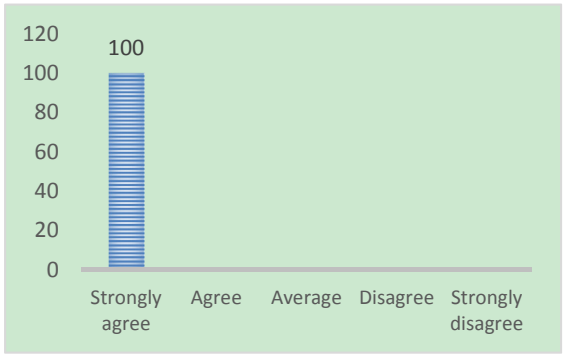
Q.10: Do you think that cars in the outdoor environment could increase the level of noise?



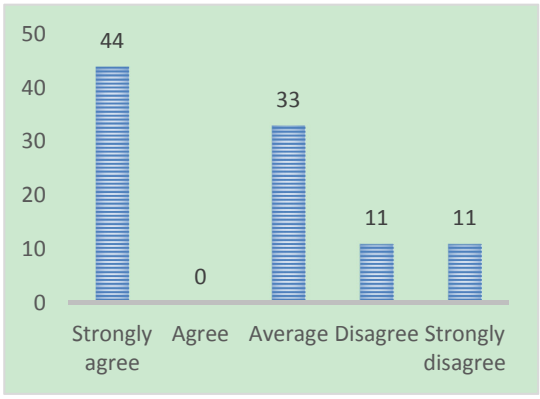
Q.11: Do you think that it's important to hire child's keeper in mosques?



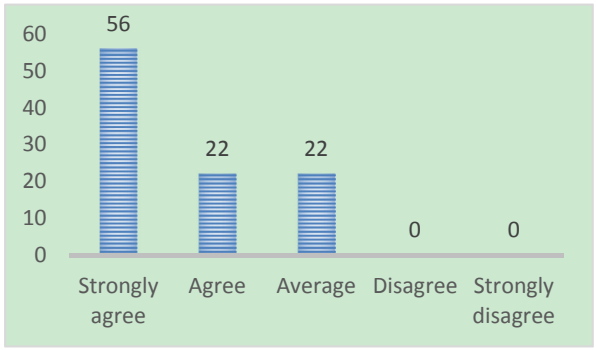
Q.12: Do you think it's important to classify the spaces into space for males, space for women's, space for Childers



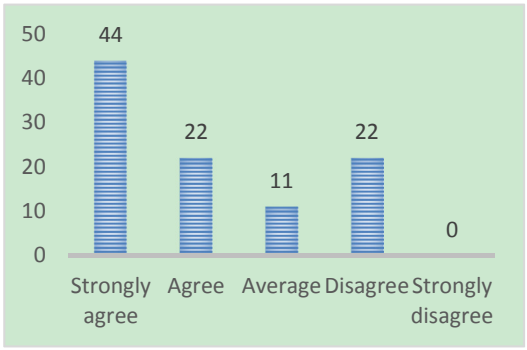
Q.13: Do you think it's important to use insulation material to absorb the noise



Q.14: Do you think it's important to use heavy construction wall to minimize the level of noise



Q.15: Do you think it's important to use carpet to minimize the level of noise



Q.16: Do you think it's important to use the smart devices to control the AC

Figure 13. The survey results

Results of sound level measurements in the case studies

3.1 Case Study One

Table 2. The result of case study one – Madina Ahujaj mosque

The pray	**Noise level on Al Subh prayer**	**Noise level on Al Thuhr prayer**	**Noise level on Al Haser prayer**	**Noise level Al Mughreb prayer**	**Noise level Al Hesha prayer**	Mean Value	
The time	5.00 am	2.00 pm	3.00 pm	5.30 om	7.00 pm	81.72	
Noise level Internally Male hall – max	86	73.8	77.3	83.9	87.6	60.22	Exceed the limit of sound level.
Noise Internally – min	63.2	56.4	49.8	64.8	66.9	68.88	within the limit of sound level.
Noise Outdoor – max	70.8	64.2	66	72.1	71.3	55.06	within the limit of sound level.
Noise Outdoor – min	54.5	52.4	52.7	61	54.7		Within the limit of sound level

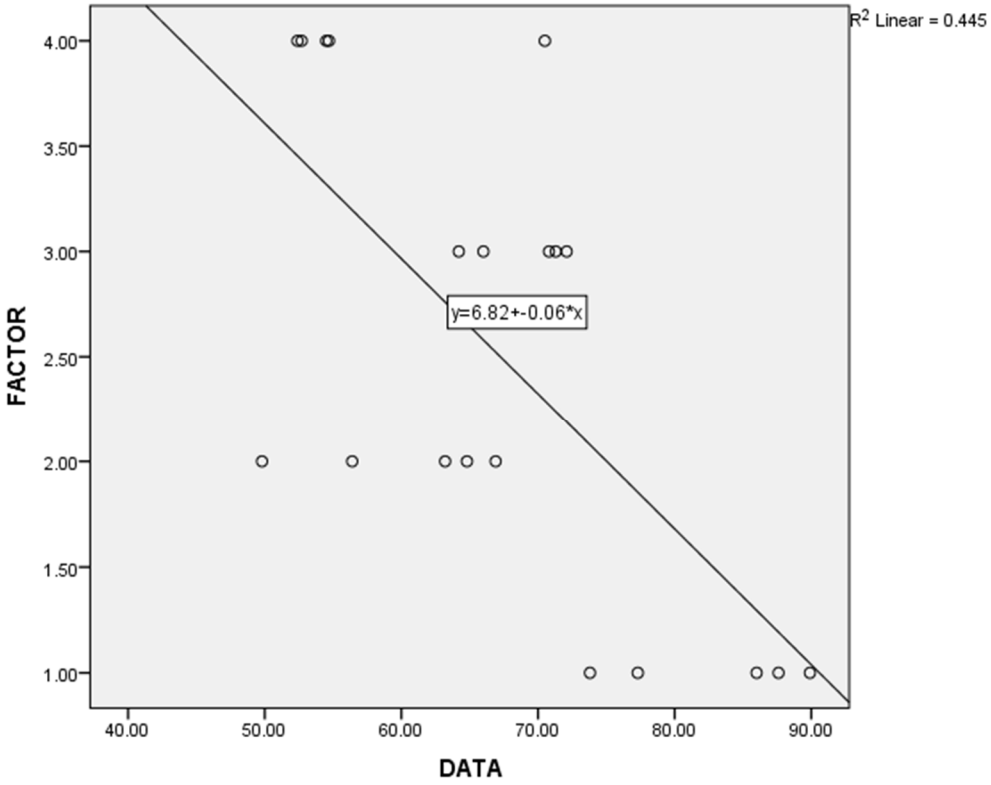


Figure 14. One-sample t-test for case study 1. ^{2} Linear = 0.0445, Y = 6.82 + −0.06X

Table 3. One-Sample t-test statistics for case study 1 showing N, mean, and standard deviation

	N	Mean	Std. Deviation	Std. Error Mean
DATA	20	67.2450	11.90668	2.66241
FACTOR	20	2.5000	1.14708	.25649

Table 4. One-Sample t-test for case study 1 showing the mean, lower, and upper values

	Test Value = 0					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
DATA	25.257	19	.000	67.24500	61.6725	72.8175
FACTOR	9.747	19	.000	2.50000	1.9632	3.0368

3.2 Case Study Two

Table 5. Sound levels in case study 2

The pray	Al Subh prayer	Al Thuhr prayer	Al Haser prayer	Al Mughreb prayer	Al Hesha prayer	Average	
time	5.00 am	2.00 pm	3.00 pm	5.30 om	7.00 pm		
Internally Male hall – max	82	76.5	74.3	85.2	83.3	80.26	Exceed the limit of sound level.
Internally – min	65.5	40.3	50.1	67.8	66.5	58.04	with the limit of sound level.
Outdoor – max	69.4	63	66.7	74.2	72.5	69.16	within the limit of sound level.
Outdoor – min	55.2	55.2	51.9	59.8	60.1	56.44	within the limit of sound level.

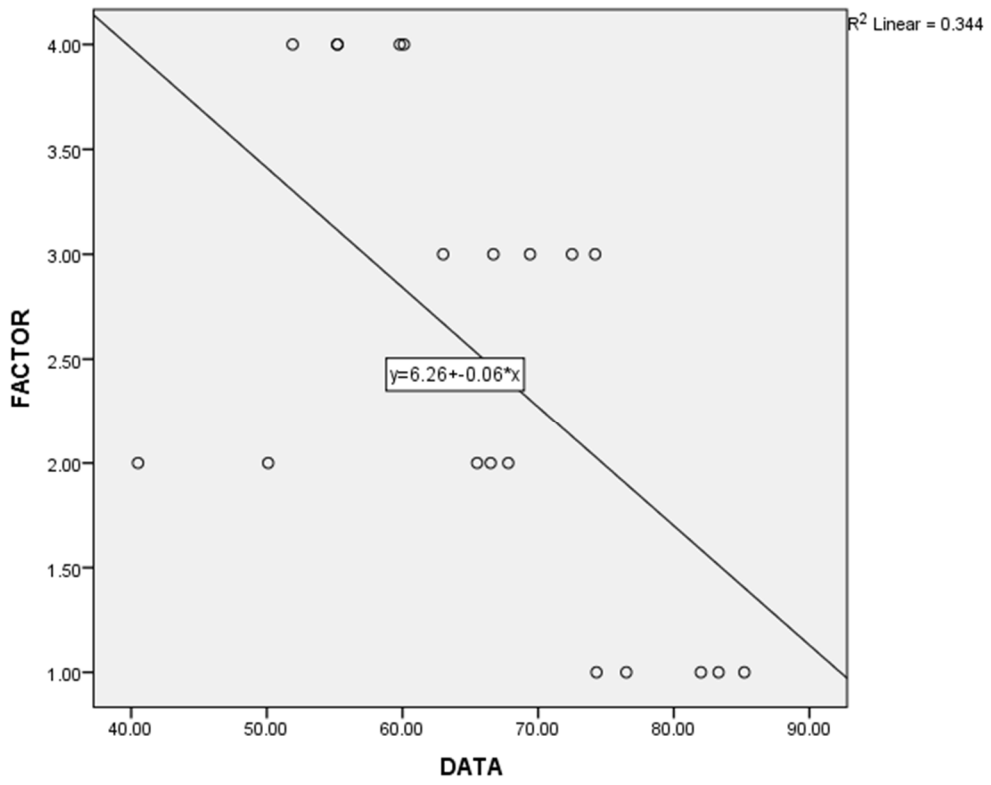


Figure 15. One-sample t-test for case study 2. R2 Linear = 0.344, Y = 6.26 + −0.06

Table 6. One-sample t-test statistics for case study 2, showing mean and standard deviation

	N	Mean	Std. Deviation	Std. Error Mean
DATA	20	65.9850	11.80041	2.63865
FACTOR	20	2.5000	1.14708	.25649

Table 7. One-sample t-test – case study 2 mean, upper, and lower values

Test Value = 0				
				95% Confidence Interval of the
t	df	Sig. (2-tailed)	Mean Difference	Difference

3.3 Case Study Three

Table 8. Sound levels in case study 3

The pray	Al Subh prayer	Al Thuhr prayer	Al Aaser prayer	Al Mughreb prayer	Al Aesha prayer	Average	Average
The time	5.00 am	2.00 pm	3.00 pm	5.30 om	7.00 pm		
Internally Male hall – max	70	67	68	70	73	69.6	With the limit of sound level
Internally – min	66	66	65	66	67	66	With the limit of sound level
Outdoor – max	86	87	85	86	87	86.2	Exceed the limit of sound level
Outdoor – min	79	79	78	79	79	78.8	Exceed the limit of sound level

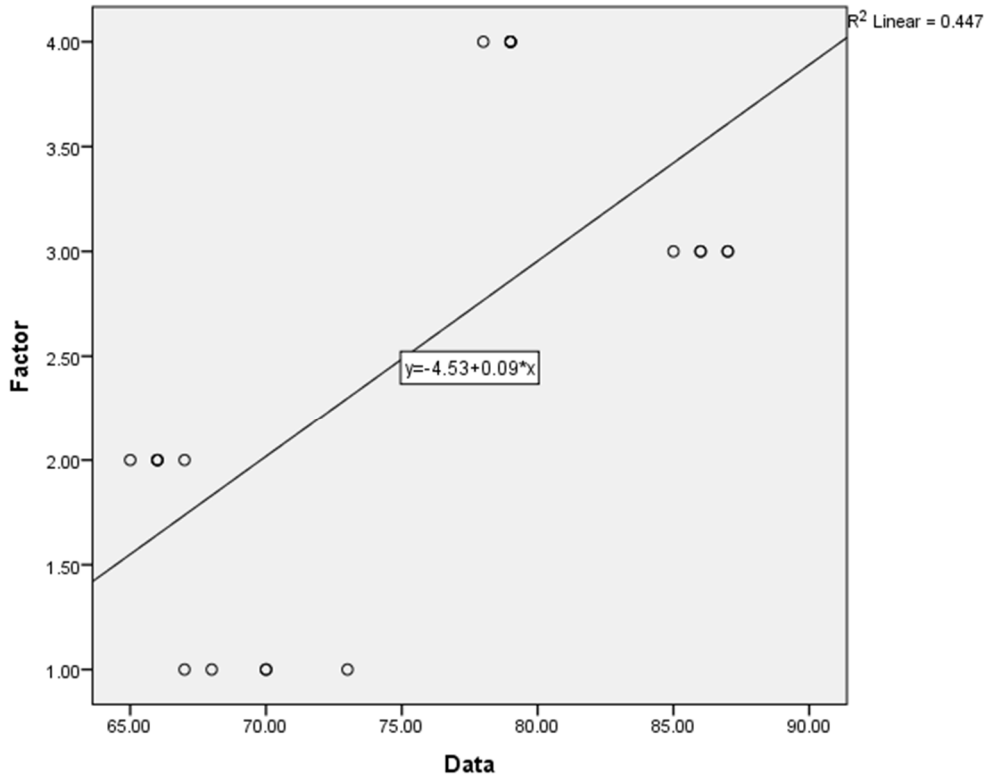


Figure 16. One-sample t-test for case study 3. R2 Linear = 0.0447 and Y = 4.53 + 0.09X.

Table 9. One-sample t-test for case study 3 – statistics, mean, and standard deviation

	N	Mean	Std. Deviation	Std. Error Mean
Data	20	75.1500	8.19676	1.83285
Factor	20	2.5000	1.14708	.25649

Table 10. One-sample t-test for case study 3 – mean, upper, and lower values

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Data	41.002	19	.000	75.15000	71.3138	78.9862
Factor	9.747	19	.000	2.50000	1.9632	3.0368

3.4 Results Justification

The results show that the maximum sound level inside the mosque exceeded the limit of hearing health (60 + 20 dB). The minimum sound level was acceptable (60 + 3 dB). However, [13] found that mosque noise levels were acceptable and in compliance with international norms of hearing safety from the National Institute for occupational safety and health (NIOSH; 85 dB). In addition, [22] found sound level reductions on the order of 6–7 dB during lockdown, with differences marked across sites and times of the day, after lockdown, sound levels gradually increased.

This research record the sound level post COVID-19 and it found that the Max record exceed the limit in the outdoor environment ±20 Db this increase because of heavy traffic light near the mosques, and the Min in the indoor is exceed the limit 60 ± 7 (Table 12).

4. Discussion

The discussion focuses on the results of four main pillars of mosque design: acoustic design, interior space, outdoor environment, and health procedures and management post-COVID-19. The survey was distributed from September to October 2022. The target group was the prayers in the Al Rawdah neighborhood in Riyadh city. The target number was 100 prayers, but only 50% of the prayers responded. The research analyzed acoustic design in three case studies. We agreed with [21] that the research should analyze multiple case studies for better results. In this research, we analyzed three case studies.

4.1 The Acoustic Design

The respondents stated that they heard the Azan in their homes. Most respondents strongly disagreed that the Azan disturbed their sleeping patterns. In addition, most respondents heard the Friday Khotba in their homes. Most agreed that the voice was disturbing them at home and that the Azan helped them wake up early. Half of the respondents agreed that the Azan encouraged mosque attendance for praying. A few respondents agreed that the sound level disturbed them.

4.2 The Interior Space

Most respondents noted that children inside the mosque were not disturbing them. Few respondents found the children disturbing inside the mosque. However, most did not agree about this question. Most respondents agreed that crowding inside the mosque increased the sound level. All respondents agreed that the designer should use acoustic material and insulation in the wall. The research agreed with [7] that the three mosques need acoustic material studies.

4.3 Outdoor Environment

Most respondents agreed that the heavy traffic and cars in the outdoor environment increase the noise inside the mosque. In addition, the environmental conditions—especially the wind and sandstorms—in Riyadh city affect the noise inside the mosque.

4.4 Health and Management

Most respondents agreed that hiring a child keeper in the mosque is important, especially inside the female prayer area. Most respondents agreed to divide the space into different functional spaces for men, women, and children. All the respondents agreed to use insulation materials in wall construction, such as a cavity wall or heavy construction walls with a thickness of 45 cm. In addition, using heavy carpets help minimize the noise inside the mosque. Most respondents agreed about using smart devices to hear the Azan at home.

4.5 Discussion of the Case Study Results

The sound level was measured with the help of two students using a sound meter to assess sound quality. In the

first case study, the indoor sound level had an average maximum value of 80 dB, while the average minimum value was 60 dB. The average maximum sound level for the outdoor environment was 68.8 dB, and the average minimum sound level was 55.04 d. This reflects the acoustic design quality based on the distance from the source. These results show that the sound level inside the mosque is high and exceeds the limit. Comparing the sound levels outdoors and indoors, the outdoor sound was lower because of the KSA legislation to limit outdoor microphones to 35 dB. By applying the SPSS t-test, the research found that the mean value for case study 1 was 67.27 dB, the upper value was 72.8 dB, and the lower value was 61.6 dB.

In case study 2, the results showed that the indoor average maximum value was 80.26 dB, while the average minimum value was 58.8 dB. The average maximum outdoor sound level value was 69 dB, and the average minimum value was 56.4 dB. These results show that the sound level inside the mosque exceeds the limit. When comparing the sound levels, the outdoor level was lower than indoors. The SPSS t-test found that the mean value for case study 3 was 65.9 dB, the upper value was 71.5 dB, and the lower value was 60.4 dB.

In the third case study, the indoor maximum average value was 67 dB, and the minimum was 66 dB, while the maximum level for the outdoor environment was 86 dB and the minimum value was 68 dB. By applying the SPSS t-test, the research found that the mean value for case study 3 was 75.15 dB, the upper value was 78.9 dB, and the lower value was 71.3 dB.

The results showed high maximum noise levels in the three mosques' interior spaces. The results agree with [8] that the acoustics inside mosques need revision. We also agree with [10] on the importance of studying the AC and air condition systems inside mosques. The research results agreed with [11] that the acoustic design inside the mosque exceeds the safe limit for human health.

4.6 The Health Impacts

Sleep disorders: Some neighbor's claimed that Azan affects their sleep.

Cardiovascular Diseases: Others said that the noise inside the mosque and from road vehicles is causing stress, high blood pressure, and heart attacks.

Hearing Problems: The microphone noise (60 ± 5 dB) may cause hearing problems.

Hearing Loss: Hearing loss is a handicap when someone has difficulty communicating in common situations, such as understanding noise around them. Such difficulties significantly affect the quality of daily life [20].

4.7 Noise Level Post-COVID-19

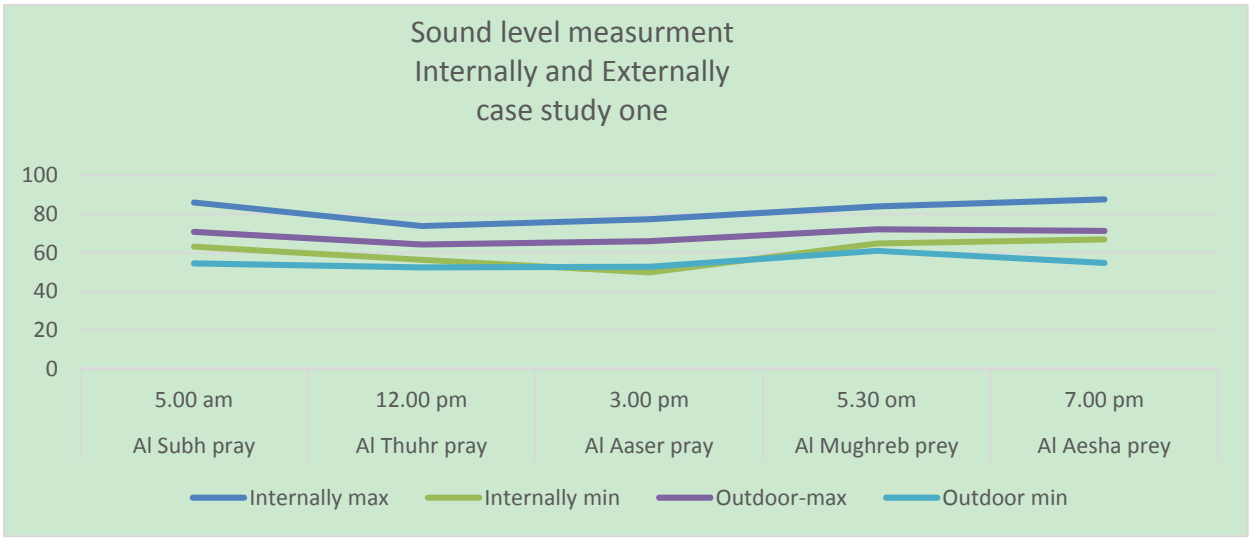
During COVID-19, the noise level reached 50 ± 5 Db [6]. This research measured the noise level in the outdoor environment; the maximum level was 68 ± 20 dB, and the minimum level was 58 ± 18 dB. The high noise range was because of heavy road traffic after the lockdown.

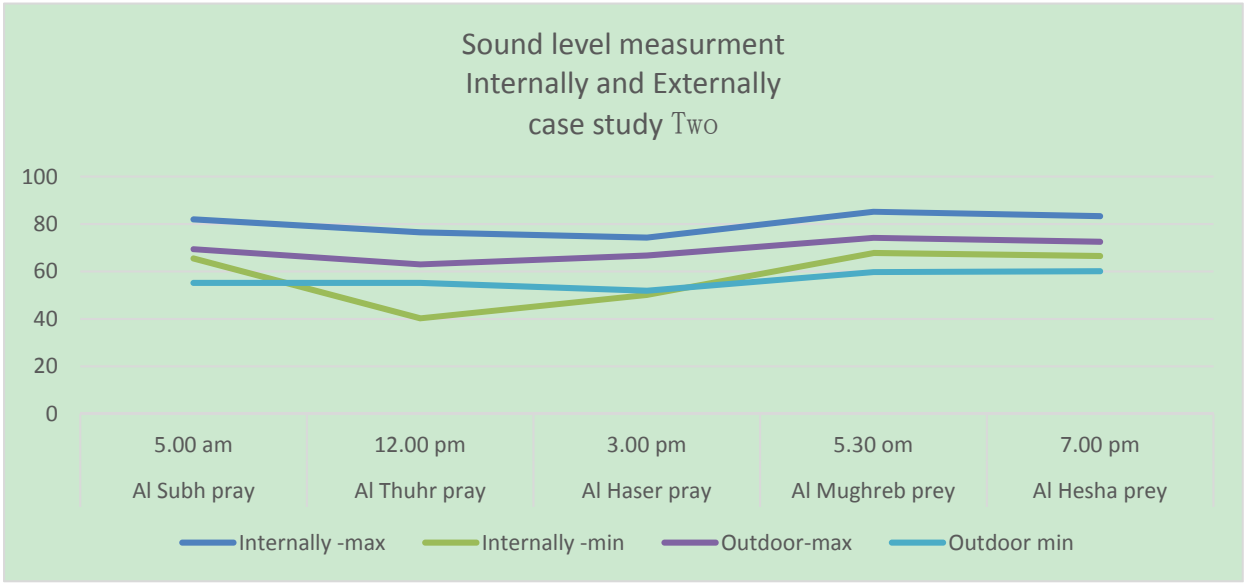
Table 11. Comparison of the three samples

Case study	Mean Value	Note
Case study one	67.2	with the limit
Case study two	65.6	with the limit
Case study Three	75.1	Exceed the limit

Table 12. Comparison of the three case studies

	Case study one	**Case study two**	**Case study three**
Internally			
Male hall-max	81.72	80.26	69.6
Internally -min	60.22	58.04	66
Outdoor-max	68.88	69.16	86.2
Outdoor min	55.06	56.44	78.8





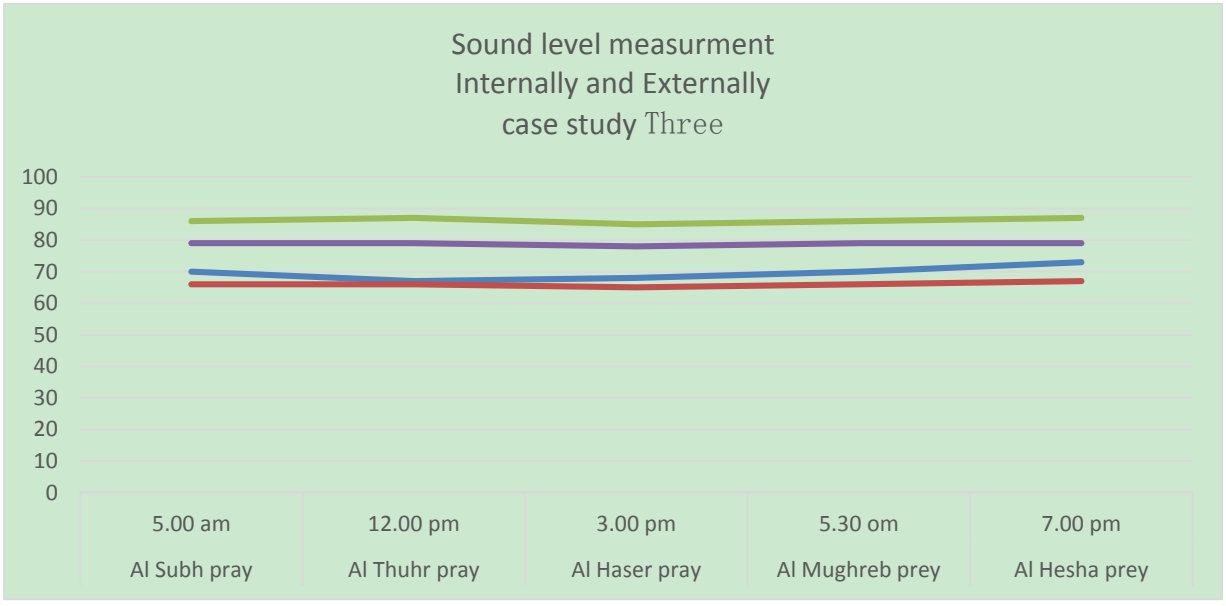


Figure 17. Comparing the results between the three case studies, internally and externally in and max

5. Conclusions

The Mosques designed in Saudi Arabia have the following acoustic design quality, with total area ratios of 1:3 and 1:2. The interior space is well equipped, the floor is covered by carpet, and the Emam and outdoor microphones are provided. The outdoor microphone sound level exceeded the standard 30–60 dB, according to LEED. Additionally, the acoustic maximum outdoor sound exceeded the limit in the three case studies (68 ± 20 dB) above the standard and minimum value (58 ± 18 dB) post-COVID-19 because of heavy traffic increasing the noise level inside the mosques. The HVAC system also affects the noise inside the mosque. The result shows that the indoor sound level is above (60 ± 7 dB), which is within the limit. The research recommends applying regular smart maintenance for HVAC systems. Additionally, children need to be safe and separate from prayers, so it is better to have a child keeper. The research encourages the regular recording of sound levels in the indoor environment using smart devices to minimize sound levels using acoustic material. For the people who do not hear the Azan at home, we recommend they use smartphone applications.

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