





The Impact of Building Façade Designs on Noise Reduction: A Case Study from Iraq

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Article Info	Abstract
<p>Received 21/04/2024</p> <p>Revised 11/05/2025</p> <p>Accepted 11/05/2025</p>	<p>This paper explores the impact of building facade designs on noise reduction in Baghdad city, where noise is a growing concern due to population growth. It identifies the influence of geometrical design details in the façade of the building and the site layout on noise reduction. The paper employs a case study, examining a two-story dwelling in a mixed-use area located near a busy road. Different acoustic measurements were conducted using a sound level meter, AutoCAD software, and additional analysis tools to assess noise levels inside and outside the dwelling. The findings indicate that balconies, noise barriers, plantations, and site layout can significantly reduce noise exposure within the dwelling. The paper emphasizes the importance of acoustic comfort in design to enhance the quality of urban living areas. As urban areas continue to expand, this research provides architects and urban designers with insights to help improve the quality of life for residents and create quieter indoor environments, and also ensure more pleasant outdoor spaces.</p>

Keywords: Architecture Acoustics, Building acoustics, Indoor noise, Soundscape design, Urban Noise

1. Introduction

Noise pollution is an issue in urban environments; it has gained increasing attention in recent years due to the growth of urbanisation and the growing population in cities [1], [2]. While urban areas continue to expand, so does the density of vehicular traffic, and other sources of noise [3]. This has led to health issues for residents, including annoyance and sleep disturbance due to being exposed to high levels of road traffic noise in and around the residential dwellings, exceeding the thresholds for a healthy environment. Noise pollution has also been linked to speech interference, stress-related symptoms, and increased risk of hypertension and cardiovascular diseases [1]. To raise the quality of the residential urban areas, current measures to mitigate the traffic noise focus mainly on lowering noise exposure on the noisiest sides of dwellings. Primarily, the measures include the use of noise barriers, insulated windows and façades, and low-noise road surfaces. However, the effectiveness of these measures in reducing the negative health impacts of noise pollution is often not inadequately assessed [4]. The important challenges highlighted in this paper are being focused on and studied by researchers in the field of architecture design, especially the aspects related to shaping facades and

geometrical details in buildings, that can contribute to noise reduction and raise the quality of living in urban residential areas [5]. However, some gaps still need to be explored and combined with the latter aspects, such as site layout, barriers, and plantation. Those combined can lead to optimising noise reduction. The study aims to address the gaps by exploring the effect of building facade designs on noise reduction and also analysing geometrical design elements that can contribute to quieter indoor environments, by conducting a thorough review of existing literature and acoustic architecture design to provide a valuable insight for urban designers, architects, and researchers involved in this area of research. It emphasises the need for a more deliberate consideration of noise reduction in urban design.

2. Literature Review

This literature review aims to examine the impact of design on noise reduction. The recent advancements in architectural acoustics highlight the importance of controlling sound in a building, particularly when attention is paid to the details that form the design. The different aspects included when shaping a building have a high impact on its acoustics [6]. Such aspects are the location of a building, room arrangement, materials,

windows, height of the building, balconies, and courtyards [7]. Design elements can produce a significant effect on the quality of sound in a building. In other words, the physical techniques have a substantial impact on noise reduction if designed in the correct way [8].

This starts at the foundation stages when designing the project, when acoustic features of the building should be taken into account. One of the most essential notes is planning the arrangements and physical techniques that can help minimize noise exposure. The acoustic design would transform a building to make it act as a noise shield [9]. The types of noise affecting us are the unwanted urban sounds that we are exposed to in our everyday lives. Those sounds are generated from different sources. The noise present outdoors has different loudness; some are loud enough to damage human hearing, [10]. One of the main goals of an architect is to provide comfort in a building design. This means maximizing the acoustic performance by improving sound quality and preventing unwanted sounds, which are defined as noise [11]. Past research shows that small changes in shaping buildings can affect traffic noise exposure, leading to a substantial impact on people's noise exposure. The study [12] examines the effect of urban design elements such as building dimensions and road type and found a significant correlation with noise perception [12]. Research shows that modifying dimensions of plans affects the acoustic environment and how it's experienced by people [13], [14]. A study done by Sanchez in 2016 shows that building facade design had an impact on noise reduction by 12.9 dB (A) when measured at windows. [15] However, there is very little information on this subject, and a lot more research needs to be done, as our environment is becoming noisier every day. This is an issue that architects and urban designers need to consider when designing buildings and shaping urban places. In contemporary urban settings, the growing population density and traffic, coupled with various sources of noise, have made noise pollution a significant concern affecting the quality of life for urban residents. This paper explores the building facades, beyond their functional roles and aesthetics, and looks at the elements as tools to compete against noise pollution. By examining the interaction between urban noise and the design of building facades, we can highlight the effect of balconies in reducing noise. This study seeks to identify how living spaces can be improved to be more acoustically pleasant, to gain a quieter atmosphere, and to create a more comfortable living environment.

Unwanted urban noise: Noise has become a growing environmental issue due to urbanization. Unwanted noise has a detrimental effect on the health and quality of life of people [10]. Noise can disrupt sleep patterns, produce stress, and cause general discomfort [16]. To tackle the noise issue, researchers have sought to reduce noise by different means. One of the methods is shaping facade designs to reduce the incidence of noise. An important factor is the construction of materials, which plays a significant role in impacting sound quality [17]. Acoustic Materials have affected areas such as architectural acoustics, urban noise control, and landscape noise [18]. This paper discusses the effects of shaping facade designs on noise reduction and the reasons behind the noise reduction of this method. The increase in noise affects people. Noise can travel

from the outdoors to the indoors, affecting the quality of life. Noise sources differ; they can range from people talking to mechanical noise. The main urban noises are categorized into two groups. The main noise is generated from transportation or construction activities, including road traffic, railway, and building sites. The other noise is from the presence of people from nearby shopping stores, cafés, and passersby [19]. The loudness of sound SPL is measured in dB (decibel)

Many aspects of architecture can be articulated to produce a variety of acoustic designs in projects [20]. They are as follows.

- Site layout and location
- Façade shapes (balconies, materials, cladding, and size and shape of windows)
- Noise Barrier
- Plantation

Site Layout and Location

Site layout is a significant action, as shown in Table 1. To reduce the impact of noise when planning any development, especially one that involves dwellings and residential buildings, as they are very noise sensitive. Typically, the act would be keeping away from general industry and commercial areas, which would be the classic recommendation when choosing a site location. However, some actions can be applied to improve the sounds. One of the significant actions in acoustical site design is building arrangement methods by orienting the residence away from the noise [21]. Taking advantage of the site's natural shape and the contours to shield noise is one of the methods used in land use planning. Another option is designing open spaces and courtyards and locating them on the site between the noise and the receiver, which can act as noise buffers or noise pockets to reduce noise impact. Placing car parking areas between noise and the receiver or dwelling location on the site is another physical technique that has a successful effect. On the other hand, the building itself can act as a noise barrier when arranged in a certain way. Shaping a building as a long, rectangular block and placing it parallel to a noisy road or highway traffic also acts as a noise shield [22].

Table1. Methods applied to site layouts for noise reduction.

Site Layout Methods for Noise Reduction	
1	Orienting the building away from the noise source
2	Making use of the site's natural shape and contour
3	Locating open spaces increases the distance between the noise and the receiver
4	Adding courtyards to act as noise buffers
5	Placing the car parks between the noise and the receiver
6	Shaping buildings as a long stripe placed in parallel with a noisy area

2.1. Facade Shape

Understanding the effect of form shapes when designing their morphology gives us the ability to improve the indoor acoustics and also the outdoor urban acoustics. The different elements that form the composition of the design of forms can create different patterns that could work as characterizing elements, which are effective in protection against outdoor noise [23]. Lee has looked at the effect of the shape on the acoustics. The results show that modifying the shapes has a high impact on noise reduction, which varies with different geometrical configurations in design. Reduction can reach up to 9dBA [24]. Facades, as part of urban areas, play an essential part in noise propagation because of their effect on sound reflections. The structure's facade in the road flume affects sound conditions. Traffic noise from the road can be reflected to the road by deck fronts and other architectural details, adding more noise [25].

2.2. Effective Features in Facades

Facades can ameliorate sound sequestration by using high-performance factors. However, it cannot be sufficient for profitable reasons. Thus, the conformation by facade shape should be taken into consideration. Usually, when architects design facades, they aim to create a balance between the structural integrity, aesthetic appeal, and functional requirements; most designers neglect the impact of adding practical features for noise reduction [26], [27]. Designing facade morphology, such as protuberances, projections, recesses, etc., as an intertwined system is an indispensable strategy that differs from using factors with high-performing systems [28]. Facade face shape can also prompt sound reflection processes, which are grounded upon the supposition that in most major metropolises, the cases of erecting façades tend to correspond to large smooth aeroplanes. They act like reflecting faces on which projections and recesses can break up diffusers due to a variety of architectural details, where there's a discontinuity of regions [29]. Balconies are an effective feature in facades. Balconies can shield the faces from outdoor noises, especially traffic noise.

Increasing the depth of a balcony reduces the noise up to 1 dB, which makes it sufficient when combined with absorbing materials. They lead to a reduction of 6.5dB in noise. The shape and form can lead to different levels of noise for people passing along the façade of the building, as it mainly influences noise levels alongside the façade. Adding objects outside next to the noise source can help in reducing noise on the lower floors of the façade of a building. Echevarria et al in 2015 examined geometrical shapes. The results from the study indicate that adding triangle shapes to the upper levels of the facade was beneficial [30]. According to Crippa et al. in 2019, adding various elements and shaping the design of the building with the right choice of cladding and materials can have a high impact on reducing noise. Adding balconies to the facade of the building makes this effect more pronounced. Many factors can affect and raise the impact, such as the location of the building on the road and the urban design settings [31]. Adding shapes and elements in facades can also improve the aesthetics of the building, which makes it visually appealing [32], [22]. A study

conducted by Ryu & Song in 2019 indicates that shape variations and urban environments can have a significant impact on reflecting or scattering the noise away from the building, which in turn prevents the noise from entering the enclosed climate [33]. Shapes with angles project sound waves; the sharper the angles of the projection, the more sound energy will be diverted in opposing directions. As the sound waves travel, their energy is reflected in multiple directions, causing them to dissipate and reduce in intensity [34]. Adding to this, the use of raised walls can create buffer zones between the sound source and a quieter area, further reducing noise also courtyards formed by the skin or walls of buildings improve acoustic properties [35], [36] The wall can act as a barrier which could have a significant impact on noise reduction in residential complexes, depending on its design and also on the urban noise form, taken into account preventing visual pollution and not disturbing the urban scene [37], [38] Noise barriers have increased worldwide because of the growing issue of traffic in cities around the world, it is considered a helpful element in urban areas and an exemplary method for noisy roads. Still, it needs to be researched and investigated more [39]-[41].

3. Research Objectives

The paper objectives are the following:

- Identify design elements in building facades that impact noise reduction.
- Specifically, investigate balconies as a practical element in reducing urban noise within the architectural indoor space.
- Review existing research on acoustic architectural design to provide an understanding of the field and to highlight the main key findings.
- To emphasize the importance of prioritizing acoustic comfort in architectural and urban design, and to create comfortable indoor environments for residents.
- To underline the need for more research in this area, especially within the increasing levels of noise in urban environments.

4. The Impact of Design on Noise Reduction/Theoretical Framework

The existing literature shows the influence of design features on the acoustic environment. Notably, the configuration of facades emerges as an important factor in shaping indoor and outdoor soundscapes, with the potential to decrease noise. However, the literature reveals certain gaps:

- Insufficient research on how shaping façade designs in residential settings influences noise reduction, particularly in mixed-use areas within Iraq.
- There is a lack of studies comparing the efficacy of diverse façade shapes in minimizing noise within dwellings.
- Inadequate comprehension of the role balconies play in facade designs and their impact on noise reduction.

Addressing these gaps could contribute valuable insights to the field of architectural acoustics.

5. Methodological Approach

The paper highlights the current lack of comprehensive research in this field and calls for further investigations, given the increasing prevalence of unwanted urban noise in our daily lives. The central goal is to contribute to the understanding of how architectural design can effectively mitigate noise, thereby enhancing the acoustic quality of indoor environments and promoting noise reduction as an essential consideration in urban planning and design.

This paper aims to explore the impact of building façade designs in a typical Iraqi house located in a noisy mixed-use neighborhood. It focuses on the balcony as an essential design element in the façade, to test its impact on noise reduction, and analyzes the geometric details that play a crucial role in this study. It also provides an overview of past literature research in acoustic architecture design and emphasizes the need for urban designers and architects to consider acoustic comfort in their designs.

The research method in this paper was conducted to provide an understanding of the impact of design on noise reduction in building facades. The research takes a quantitative approach for data collection, focusing on field measurements taken at various times of the day to quantify urban noise, particularly from nearby road traffic. To comprehensively assess the noise impact, noise measurements were also conducted inside dwellings, specifically in two different rooms—one with a balcony and one without. By measuring noise levels in these distinct environments, the study aims to understand the effect of design features on noise reduction. A sound level meter was used to measure noise at various locations within the rooms to determine how the design influences noise levels. The collected measurements were analysed to evaluate the effectiveness of different noise reduction designs, focusing on the effect of the balcony in the façade. Although the primary focus was on facade design, the study also considered other factors that can affect noise levels, such as the presence of barriers and site layout. These aspects are further explained in the case study section. For example, the building orientation, the use of the natural site contours, and the arrangements of open spaces and courtyards can serve as noise buffers, improving the effectiveness of noise reduction strategies. Barriers such as the car park, rectangular buildings placed parallel to noisy areas, were also investigated for their potential to mitigate noise. By incorporating these distinct factors, the research offers an understanding of how architectural and site design can be used to reduce urban noise. The results aim to provide practical guidance and insights for architects, urban planners, and policymakers to improve the quality of life for urban residents and to enhance it through effective noise control strategies.

6. Case Study

The case study focuses on a two-story dwelling selected along a 10m wide street in a mixed-use area, as in Fig.1, combining both residential and commercial purposes. This district is located in the center of Baghdad, Almansoor district, as shown.

It's the map. It represents a busy and lively area throughout the day and night with diverse activities. The area is a mix of residential and commercial buildings with a constant flow of traffic. In this dynamic neighborhood, the noise emanates from various sources, ranging from passing cars, car horns, and the chatter of pedestrians to the occasional shout or the buzz of motorbikes and bicycles. Construction noise can also punctuate the soundscape, adding to the traffic noise of this vibrant urban environment.

The building's facade in this context becomes an intriguing subject of study, as it must contend with the multifaceted challenges posed by this rich complex of urban life, and its design and features may significantly influence the overall urban experience and acoustic environment. The house is located on a noisy road, as in Fig. 2. The noise travels inside the houses. Residents complain of the constant noise.

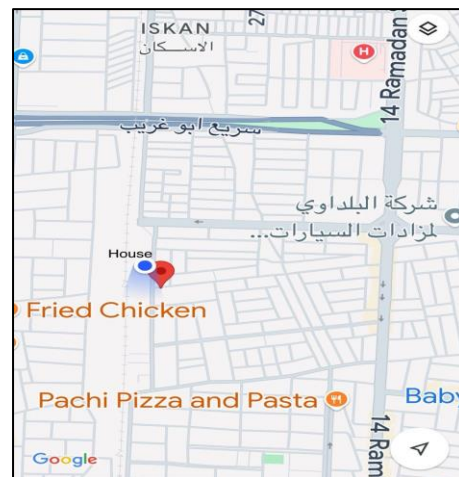


Figure 1. House location (source: Google Maps)



Figure 2. busy road view (Source: Authors)



Figure 3. Façade of the selected dwelling for the case study

The selected sample house has a total height of 7 m, featuring a façade that stretches for 14 meters. Notably, the balcony is positioned on the first floor, with its base situated 3 meters above the ground level, providing an elevated perspective of the bustling surroundings. A concrete canopy covers the built area of the house, as shown in Fig.3. This architectural configuration has the potential to significantly impact the interaction between the building and the dynamic urban environment it overlooks.

In the case study, the dwelling has a 2m high wall fence, see Fig.4. Its width is 0.3m and it serves as an experimental component in the study to assess its effectiveness as a noise barrier surrounding the dwelling. The fence is located 10 meters from the façade.

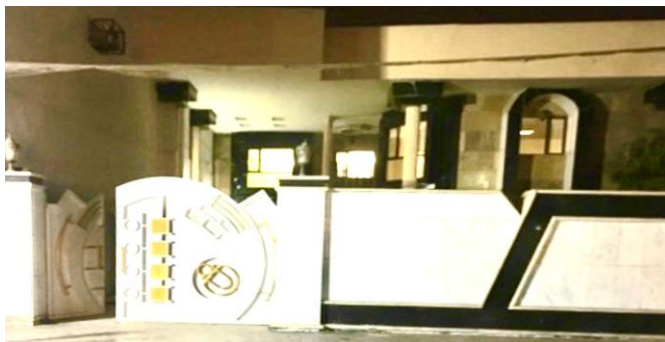


Figure 4. Image of the stone fence wall

The dwelling is attached on both sides with neighbors' houses and a fence, which makes it an enclosed space with a garden and driveway, with dimensions of (10m x 14m). The house is constructed with typical building materials used in Iraq, which are formed from bricks combined with concrete. In addition, the cladding used in the façade is natural stone, a typical material used in many building practices in Iraq, because of its durability and for enhancing both the structure and aesthetics of the buildings. The case study will evaluate how the façade design affects two rooms inside the dwelling. With windows facing the noisy road, Room 1 is a bedroom without a balcony, and Room 2 is a sitting room connected to the bedroom with a balcony alongside the stone fence, to measure the impact of the house's exposure to external noise sources in the lively urban environment.

6.1. Equipment, Software, and Measurements

The study employed specific equipment and software for conducting acoustic measurements:

- A Sound Level Meter (SLM): The measurements of acoustic parameters, especially the Sound Pressure Level (SPL), were carried out using the model TES-1350A sound level meter, with a wind shield, which is compliant with international standards such as IEC651 and ANSI S1.4, to ensure the accuracy and reliability of the experiment—fig. 5.
- AutoCAD Software: This was used for the architecture drawing for the first-floor plan of the dwelling. The illustration represents the locations of the measurements conducted for each room, as well as a drawing of the site and the nearby road, created using AutoCAD software.
- NIOSH SLM Software: This software is developed by EA LAB, and is used in a case study for the calculation of critical acoustic parameters such as the Maximum Level of noise exposure and the Time-Weighted Average (TWA) noise levels. NIOSH (National Institute for Occupational Safety and Health) guidelines are used in occupational and environmental noise exposure assessments.



Figure 5. A Sound Level Meter with a wind shield was used in tests.

The measurements were conducted at three different times throughout the day:

1. In the morning from 8:00 am. To 8:30
2. During the afternoon from 2:00 pm.- 2:30 pm
3. In the evening from 9:00 pm.to 9:30 pm

It is important to note that weather conditions were partly cloudy, no wind or rain, with a temperature of 28 °C on the day of the test. These time points were chosen to capture a variety of

noise levels during the day. The measurements were taken in both Room 1 and Room 2, inside the house, as pointed out in

the AutoCAD drawing in Fig.6, both of which are located on the first-floor level facing the noisy road.

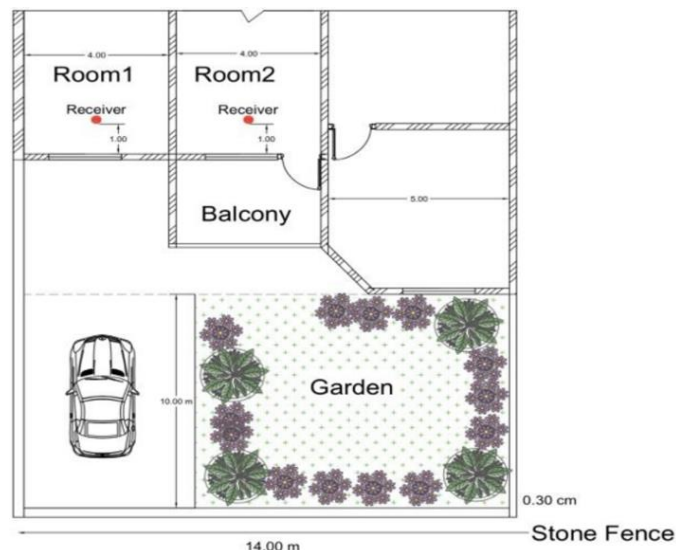


Figure 6. Stimulated drawing of the off-site layout and location

Before conducting the measurements inside the rooms, background noise was measured in two key locations:

Table 2 shows urban noise (mainly from road traffic) at different times of day.

Location of test	Time of test	LAeq60secdB	Max lev. (dBA)	TWA (dBA)
Outside fence wall (Location 1)	Morning 8:00 am	97.5	106.2	71.2
	Afternoon 2:06 pm	97.7	113.4	71.4
	Evening 9:12	95.1	110.3	68.0
Inside fence wall (Location 2)	Morning 8:00 am	87.6	100.0	60.9
	Afternoon 2:00 pm	85.3	90.6	59.0
	Evening 9:00 pm	83.6	89.2	56.8

Table 3 shows noise inside Room 1 & Room 2 (mainly from traffic) at different times of the day.

Location of test	Time of test	LAeq60secdB	Max lev.	TWA
Room 1 (without balcony)	Morning 8:00 am	72.8	95.6	42.4
	Afternoon 2:20 pm	77.6	102.0	51.8
	Evening 9:24 pm	72.9	97.1	46.3
Room 2 (with balcony)	Morning 8:00 am	68.6	72.6	35.6
	Afternoon 2:15 pm	72.6	95.2	49.2
	Evening 9:06 pm	70.8	93.1	39.6

7. Results

7.1. Site Layout and Location

Analyzing the site layout of the dwelling through a simulated drawing reveals that it is situated on a busy street. The

- Outside the wall fence on the pavement (0.50m from the road).
- Inside the fence (0.50m away from the fence).

Table 2 shows urban noise (mainly from road traffic) at different times of day. Measurements inside Room 1 and Room 2 took place in the morning, afternoon, and evening, as shown in Table 3. The Sound Level Meter (SLM) used for the measurements was handheld at a height of 1m and at a horizontal distance of 1m from the window and wall facing the busy road. This setup is a standardized measurement and ensures a reliable test. The specific locations are illustrated in Fig.6. The measurements aim to assess how noise levels vary in the dwelling at different times of the day and how the balcony on the façade can influence noise exposure.

The A-weighted Leq for traffic noise at different locations in the case study, both behind and outside the stone fence, measured at various times of the day, is shown in Fig.7. Additionally, Fig.8 presents the A-weighted Leq for different facade arrangements, with and without balconies, measured inside Room 1 and Room 2 at other times of the day.

building's facade is enclosed by tall walls, effectively creating a courtyard-like space that includes a garden and a driveway. Within this courtyard, various plant beds are strategically placed against the inner walls, forming a noise buffer similar to that of a courtyard. As shown in Fig.9, sound measurements

taken at the center of the garden demonstrate a notable reduction of 10 dBA in noise levels.

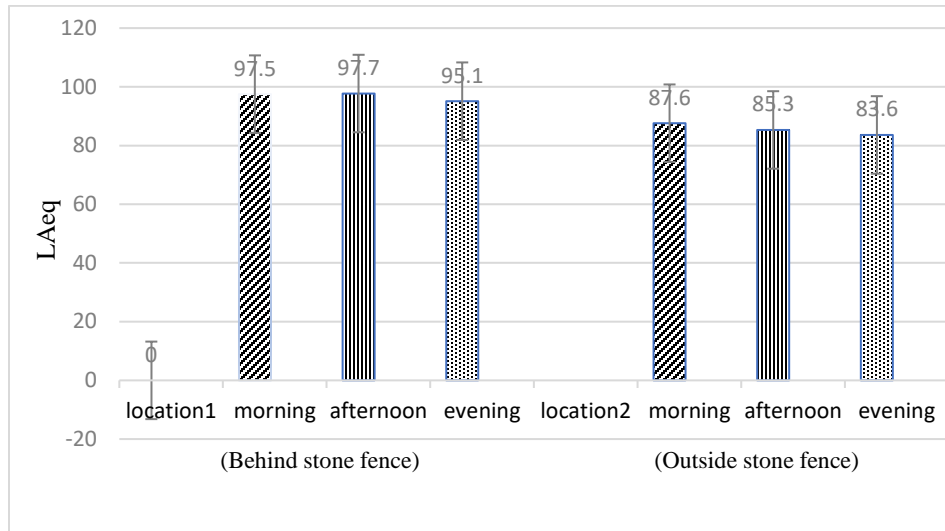


Figure 7. A-weighted Leq for traffic noise related to the different locations

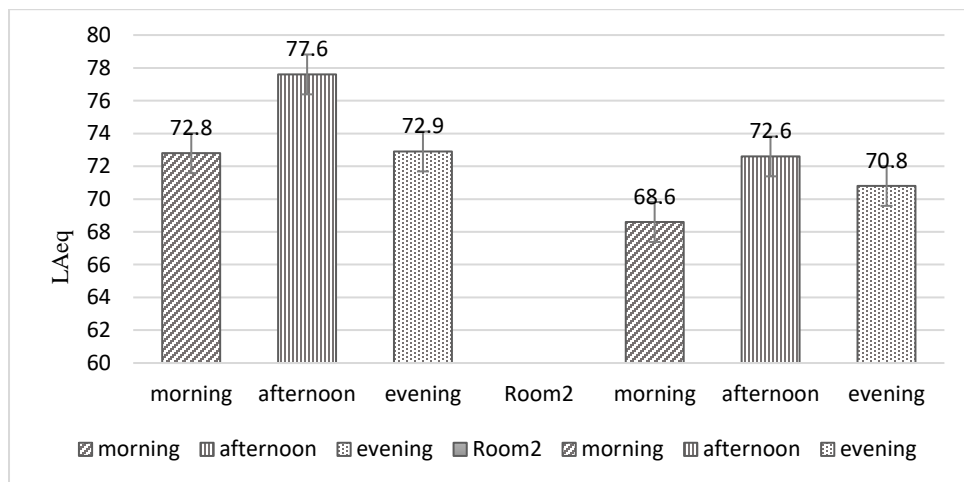


Figure 8. A-weighted Leq related to the different façade arrangements

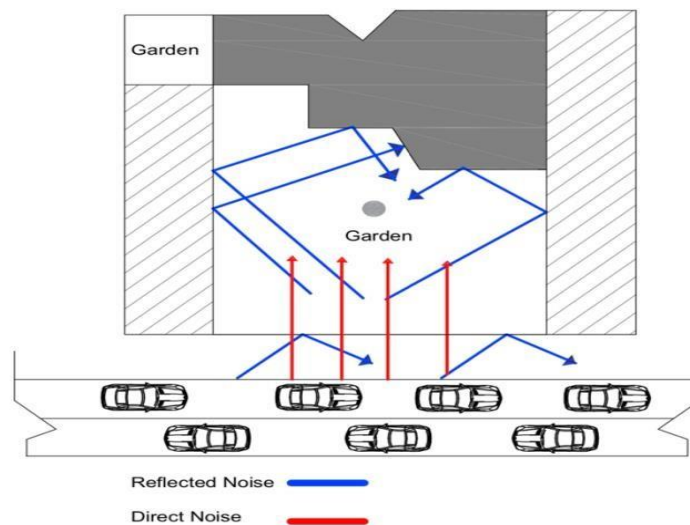


Figure 9. Simulated drawing of site layout and location

Noise Barrier

Referring to the data presented in Table 1, which illustrates urban noise levels both outside and inside the dwelling, it is evident that the stone fence serves as an effective noise barrier, isolating and redirecting noise away from the building. When comparing the Leq results, there is a significant reduction of approximately 10 dBA. The combination of the fence material and its height, along with the presence of the plantation, collectively functions as a crucial element in forming a noise barrier for the tested dwelling.

7.2. Balconies in Façade

Observing the data in Table 2, it becomes clear that there is a noticeable decrease in noise levels between the two measured rooms, Room 1 (without a balcony) and Room 2 (with a balcony). Upon comparing the results, it is evident that the Leq in Room 2 exhibits a reduction of approximately 4-7 dBA at various times of the day.

7.3. Noise Exposure

The overall noise exposure for urban noise levels that mainly was from road traffic was measured at different times of the day outside and inside the dwelling and from the data collected it can't be highlighted that the noise exposure with higher levels what observed during busy traffic hours during the daytime adding to that particular design features that were studied such as balconies has an impact on reducing the overall noise exposure an indoor environment emphasizing the influence of details of design features.

8. Conclusion

This paper aimed to investigate the impact of shaping forms and facades on noise reduction in urban settings in Baghdad, Iraq. The findings highlighted that facade shapes, site layout, noise barriers, and greenery play a key role in enhancing the acoustic performance of buildings. These factors were shown to significantly lower noise levels, improving the residents' quality of life. The study emphasises the importance of incorporating noise reduction strategies in architectural and urban design. By prioritising these aspects, architects and urban designers can design quieter indoor environments and more enjoyable outdoor spaces, enhancing the well-being of urban dwellers.

9. Recommendations

The results and findings of this paper's methodology suggest that noise barriers are highly effective. Additionally, paying attention to site layout within the design process can impact noise reduction. The paper highlights features such as balconies, which play a significant role in contributing to a quieter and healthier indoor environment. While providing valuable insights, it is evident that further research is needed to identify gaps. Limited research exists on the effect of facade design in residential areas in Iraq, and there is also a lack of comprehensive research comparing different facade shapes and site layouts and their impact on noise reduction in urban environments.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Author Contribution Statement

Tahrir Taki Ali Almusawi: Proposed the research problem, conducted the initial writing, performed data analysis, and provided overall supervision of the research.

Ashwaq Fadhel Muhkaber Alomare: Discussed and interpreted the results, ensured the validity and efficacy of the findings,

Lina Kifah Kadhum: Compiled and formatted the tables and contributed significantly to the final version of the manuscript.

Zainab Qahtan Abd Alrazzaq Alkhayat: Discussed the results and contributed to the final manuscript

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