Journal of Salutogenic Architecture

Original Scientific Paper 2022, Volume 1, Issue 1, pages 1–18
https://doi.org/10.38027/jsalutogenic_vol1no1_1

The Acoustic Performance Assessment in Residential High-Rises as a Salutogenic Approach in Design: Erbil – Kurdistan Region of Iraq as a Case Study

Hadar Ihsan Ali
M.Sc. in Interior Architecture, Tishk International University-Erbil, Iraq.
Email: hadaralkraidi@yahoo.com
https://orcid.org/0000-0003-3709-5405

Abstract
The acoustic level in the building is one of the critical design criteria for the privacy and comfort of occupants in the approach of salutogenic design. This attempt to study noise levels in Erbil residential high-rises is hardly described in the literature. This study focuses on the noise level in high-rise residential buildings in Erbil, Iraq. A comparison between two famous residential towers in Erbil has been achieved to evaluate the noise level and find the acoustical advantages and disadvantages of those buildings. Analysis of the plans, direct measurement of sound level, and questionnaire, have been applied as primary sources, for this purpose through five channels (outer and inner noise sources analysis, identifying direct sound transmission, indirect flanking sound transmission, perception of the occupants' noise level, and empirical noise level finding). Secondary sources such as books, magazines, and credible internet sources, have been used too. The results demonstrated that commonly, the occupants in both buildings are suffering from acoustical discomfort. However, the shape and form of the building, its location, and construction material can create advantages for one building over another in terms of acoustic results. the result of the current paper can help the designers to take good design decisions in the future in the region of the study.
Keywords: Noise, Buildings' acoustic performance, Salutogenesis, MRF Towers, Park View Buildings.

Article History:

Received: 05-08-2022
Revised: 12-09-2022
Accepted:18-09-2022
Available online: 19-12-2022

1. Introduction
The Kurdistan Region of Iraq has witnessed a gigantic development in terms of building construction (Muhy Al-Din, et al., 2017; Shawkat, et al., 2018). Multi-story residential buildings have been remarkably observed in the city fabric and invaded the residential sector in the last decade. Consequently, residential buildings started to change from houses to apartments progressively, as a result of the increment in land price and population. People in Kurdistan of Iraq are newly experienced in living in apartments. The noise level of acoustic performance in the apartments is crucial for the implementation of privacy and comfort. Since, the salutogenic approach goes beyond the more conventional, pathogenic concern of risk and issues to place greater emphasis on elements that promote a healthy lifestyle. This approach is generally employed worldwide, including in the fields of health, education, workspaces, and architectural design, (Golembiewski, 2022). To approach salutogenic architecture to achieve health and well-being through the design, Architects and interior architects have a significant role in achieving better acoustic performance or reducing the level of noise, through the management of interior spaces as well as materials. The development of new design strategies and construction techniques can result in improvements in the total building quality, and comfort for occupants to achieve Salutogenic design. Acoustic performance is a substantial aspect is one of the important approaches to be implemented in architectural design to control noise (Bragança and Patrício, 2004). Highly developed countries use a combination of both technological and legal approaches to reduce noise pollution that emanates from different sources by applying different mechanisms such as maintenance of automobiles; low voice speaking; reducing noise levels from domestic sources; prohibition on the usage of loudspeakers; selection of types of machinery and maintenance of

How to Cite this Article:
Ali, H. I. (2022). The Acoustic Performance Assessment in Residential High-Rises as a Salutogenic Approach in Design: Erbil – Kurdistan Region of Iraq as a Case Study. *Journal of Salutogenic Architecture,1*(1), 1-18.
https://doi.org/10.38027/jsalutogenic_vol1no1_1

existing machines. Whereas awareness about the design for acoustic performance is lacking in our country, and still, there seems to be a great reluctance from the responsible authority side to implement the acted rule and regulations. It is worth mentioning the high annoyance of 6.5% of the population by the noise of neighbors. Neighbor’s annoyance apart from other types of noise, such as traffic, industry, airplane, railways, etc., is considered one of the most annoying. Where the research, addressed that 80% of people are suffering from neighbor noise annoyance (Thaden, 2005). The paper aims to reach a comprehensive understanding of the acoustic performance and noise level in the apartments in Erbil, the capital of the Kurdistan region of Iraq.

Furthermore, tries to come out with specific findings that may contribute to improving the current building regulations and suggest new criteria in terms of acoustic performance in apartments. The paper assigns the following questions; how much acoustic performance in multi-story residential buildings in Erbil is comfortable? To what extent, do the designers follow the acoustic performance criteria and regulations in the design of Residential multi-story buildings in the Kurdistan region of Iraq? The paper's objective is to evaluate the acoustic performance and acoustic comfort of multi-story residential buildings in Erbil, the capital of Iraqi Kurdistan. To determine the primary objective, the following specific secondary objectives were to; 1) Investigate noise levels in different apartments within the city of Erbil; 2) Examine the interior space division in the design of these apartments and their effect on Noise level; 3) Determine the surrounding built environment on the noise level in the apartments; 4) Evaluate the effectiveness of building construction material of the apartment buildings on the acoustic performance. For this purpose, several multi-story residential buildings have been selected from two dwelling projects in Erbil as case studies (Park View & MRF Towers). These buildings have been analyzed acoustically, and comparative analysis among them will be carried out in order to answer the questions assigned in this paper.

2. Literature Review

2.1 Salutogenesis theory in Architecture

Salutogenesis is a scientific approach that focuses on the study of the origins of health and resources for health, rather than studying the causes of disease and risk factors, (Mittelmark and Bauer, 2016). The term was first used in Health, Stress, and Coping by American medical sociologist Aaron Antonovsky, (Golembiewski, 2022). It can be defined as a method of studying human health that focuses on elements that promote and maintain physical and mental well-being rather than the disease, with a focus on how people cope with stressful situations in order to maintain their health (Antonovsky, 1996). The word "salutogenic" has permeated hospital design and it is entering the fields of elderly care, education institutes, and workplaces. The phrase was created to explain Antonovsky's theory on the effects of society and the environment on health. However, in the hyperbole of most designers, providing views that represent nature—whether they be vegetation (designed public parks, open fields, plants, etc.), views of the sky, or even picture representations of these things—means little more than vague motivations to generate reparative environments. As a result, the theory is frequently stripped of all of its potentials. Salutogenic theory has far more to offer the architectural design field than it now does (Golembiewski, 2022). Therefore, human comfort inside the buildings is one of the essential factors to achieve salutogenic architecture. The comfort inside the building is related to many factors, like thermal, visual, and acoustic. Hence, acoustic design is one of the main factors to approach salutogenic design in buildings.

2.2 Noise

Noise is defined as “a sound or sounds, especially when it is unwanted, unpleasant, or loud” (Cambridge Dictionary, 2018). Moreover, noise is a disturbing wave that impacts negatively health. It has become an obvious stress factor in the human beings' environment due to the development of technologies and industries. The best distinction between “Sound” and “Noise” is sound is desirable and noise is not. This definition does not consider the content of the sound. Regardless of the irritation and discomfort, noise pollution can cause harm based on its concentration, duration, and frequency. The problem of noise is growing and coincides with an increase in people’s complaints about their suffering from noise. Several organizations such as World Health Organization, International Labor Organization (ILO), and Occupational Safety and Health Administration (OSHA) have put new regulations and standards to control noise, and the required actions against the sources of noise (Komla, 2012). See Table ‘1’.

Table 1. Some noise standards by World Health Organization (WHO, 1999).

Area Code	Category of Area/Zone	Limits of L_{eq} dB(A) Day Time	Night Time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence Zone	50	40

Note. L_{eq}: **The equivalent continuous sound level**

Many sources have identified the space's comfortable acoustic level standards, as per the functionality of the space, as seen in Table '2'.

Table 2. Room and spaces acoustic comfortable standards. (Hansen, 2000).

ROOM/SPACE	DBA	NR	NC/NCB	RC/RCM2
Theaters, Concert Halls, Recording Studios	25-30	20	10-20	20
Bedrooms, Libraries, Religious Prayer Rooms	25-30	25	20-25	25
Living Rooms, Classrooms, Lecture Halls, Conference Rooms	30-35	30	30-40	30
Offices, Courtrooms, Private Work Rooms	40-45	35	30-40	35
Corridors, Open Offices, Bathrooms, Toilet Rooms, Reception, Lobbies, Shopping	45-55	40	30-40	40
Kitchens, Shopping, Common Spaces, Dining Halls, Computer Rooms, Workshops	45-55	45	40-50	45

2.3 Decibel and dB Level

The international unit of sound measurement is 'The decibel (dB)'. It is a measure of sound pressure measured by a meter that registers and displays these readings on a sound level scale. Decibel units are logarithmic, the difference between values increases with increasing the values, which means a noise measuring 20 decibels is actually 10 times louder than a noise registering at 10 decibels. The decibel is an important parameter related to noise, acoustics, and hearing. It is a unit of characterizing sound pressures, which is based on a logarithmic gauge. It prevails in use as the fundamental measurement in acoustics, and the reason behind that is that the ear itself 'hears' logarithmically and human beings judge the relative loudness of two sounds by the ratio of their intensities, a logarithmic behavior. The ear also has an extraordinary range and using a logarithmic decibel standard assists to keep these massive numbers under dominance. The logarithmic measure is used for the comparison between the reference value and the quantity of interest; a prevalent example is the threshold of hearing, which refers to a 20 Pascal micro sound pressure level or a sound power of 1 pico-watt (Katz, 2010). For an obvious understanding of the method that logarithmic signals work, consider two uncorrelated sounds in one room. If both separately have the same level of noise, then the summation of these two would give a total noise level that is 3dB greater. The sound levels in the city depend on the distance from the noise source. Some frequently heard sounds and their approximate decibel levels at common distances from the noise source mentioned below (A Guide to New York City's Noise Code, 2007).

Whisper .... 30 dB
Normal Conversation/Laughter .... 50 – 65 dB

Vacuum Cleaner at 10 feet............................. 70 dB
Washing Machine/Dishwasher....................... 78 dB
Midtown Manhattan Traffic Noise.............. 70 – 85 dB
Motorcycle... 88 dB
Lawnmower .... 85 – 90 dB
Train .... 100 dB
Jackhammer/Power Saw............................. 110 dB
Thunderclap .... 120 dB
Stereo/Boom Box...................................... 110 – 120 dB
Nearby jet takes off...................................... 130 dB

The louder the noise means the higher the number of decibels. The louder the noise, the greater the risk of hearing loss occurs. Hearing loss can occur if the human exposure for longer than' one minute' to noise levels of 110 decibels or more. No more than 15 minutes of unprotected exposure to 100 decibels is recommended. Long-term exposure to 80-85 decibels or over can cause hearing loss (Claridge, 2007). Figure '1', demonstrates the common sound sources plotted at their dominant frequencies and levels as typically heard by observers.

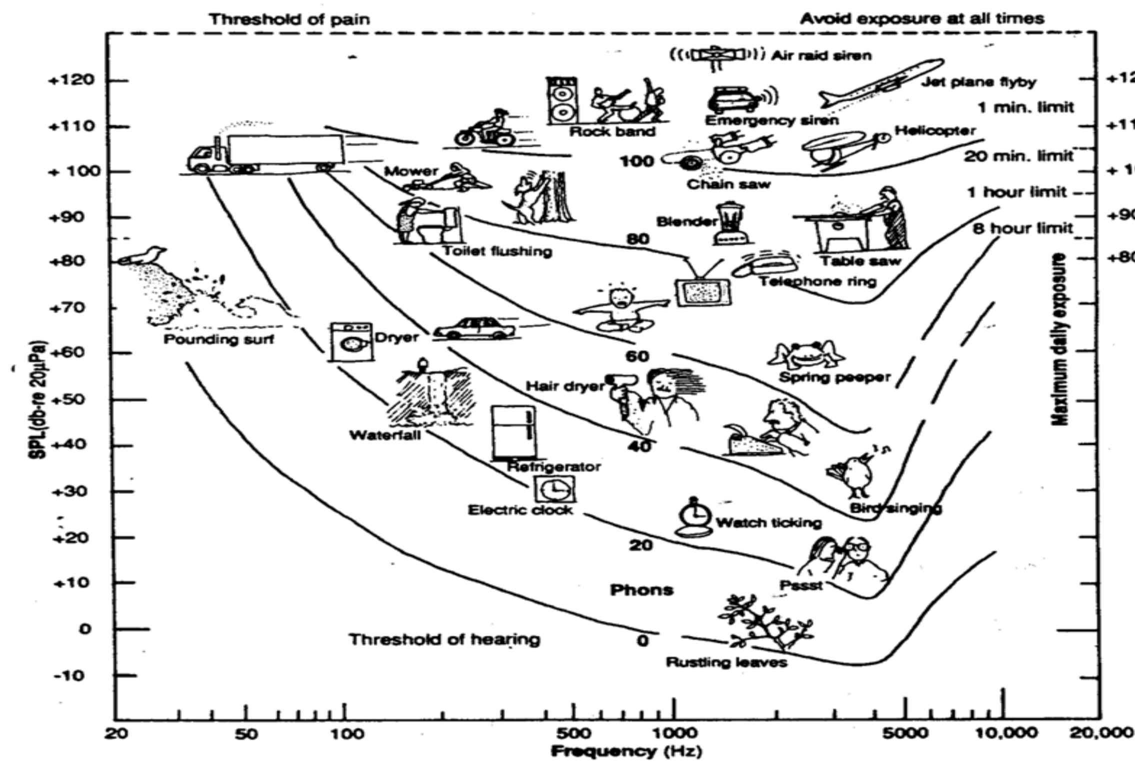
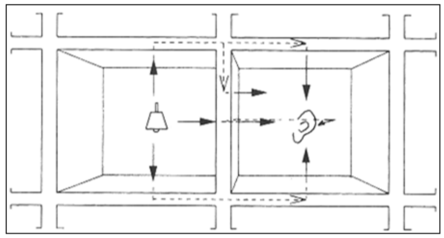


Figure 1. Common sound sources with their dB level and Frequency (Berendt, *et al.,* 1978).

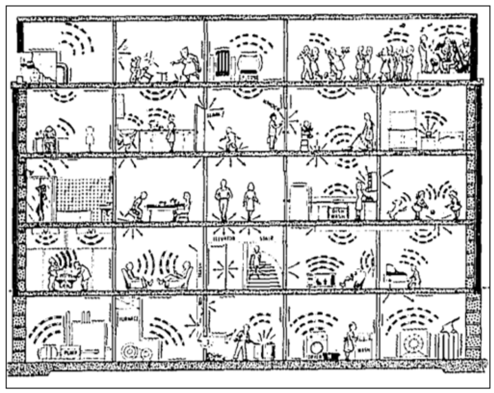
2.4 Building's Acoustic Performance

Sound is defined by the Oxford dictionary as "Vibrations that travel through the air or another medium and can be heard when they reach a person's or animal's ear." (Oxford Dictionary, 2018). According to Meisser (1978), "Sound" is, the prevalence of pressure and depression waves, which can be detected by the human ear. If a wall is introduced to pressure and depression waves it will vibrate sending a sound with a frequency equal to that sent by the source. This transmission of sound depends on the energy of the acoustic waves that hit the wall and on the interior structure of the building. In building acoustics there are two main types of sound prevalence that can be recognized, namely; the airborne sound and the structure-borne sound or (impact sound). There are three main transmission ways among adjacent rooms as seen in Figure '2-a';
1) Transmission, directly through joints, discontinuities, and cracks; 2) Transmission, directly because of the vibration of the partition itself; 3) Flanking transmission, (indirectly).

The decrement in the transmission of airborne sound between the source room and the receiving room is known as airborne sound insulation. The structure-borne sound, which happens by steps sound of walking people, the movement of chairs on the ground, the falling of objects on the ground, etc., i.e., the sound energy that reaches the receiving room due to an impact hit. See Figure '2-b'.



(a)



(b)

Figure 2. (a) sound of transmission ways between adjacent rooms (Braganca and Patriciol, 2004); (b) common indoor sources of noise (Berendt, et al., 1978).

However, the reduction of the propagation process in the receiving room, related to impact sound, is called impact sound insulation. The flanking transmission is identified by the type of element and edge conditions. The sound insulation between two adjacent rooms can be lower than expected with the presence of high-flanking transmission. The resilience of the walls to the sound is depending on the type of walls as follows:

A. Massive walls

Massive walls, such as brick or concrete block masonry walls, are not usually used in buildings because they are very heavy. The sound insulation of this type of partition is almost entirely influenced by its mass per unit area. Other factors with less influence are the loss factor, the stiffness, and the bending conditions. In the case of the use of these types of walls in steel construction, it's important to insulate the steel profiles from the walls and enclose them with a resilient separating lining in order to avoid vibration propagation to the steel structure.

B. Lightweight board walls

Lightweight board walls are the most commonly used solutions to make partitions and separate walls in buildings. This type of wall can be made with a single frame or a double frame supporting single-leaf or double-leaf boards.

For lightweight board walls, normally, less mass is required to achieve the same sound insulation as in the case of massive walls. But the elastic characteristics of the board leaves have to be carefully chosen to locate the coincidence frequency below the 100 Hz frequency band. The sound insulation of lightweight board walls is not influenced by the steel supporting frames provided the boards are effectively separated from the construction (Cremer and Heckl, 1973). See Figure '3'.

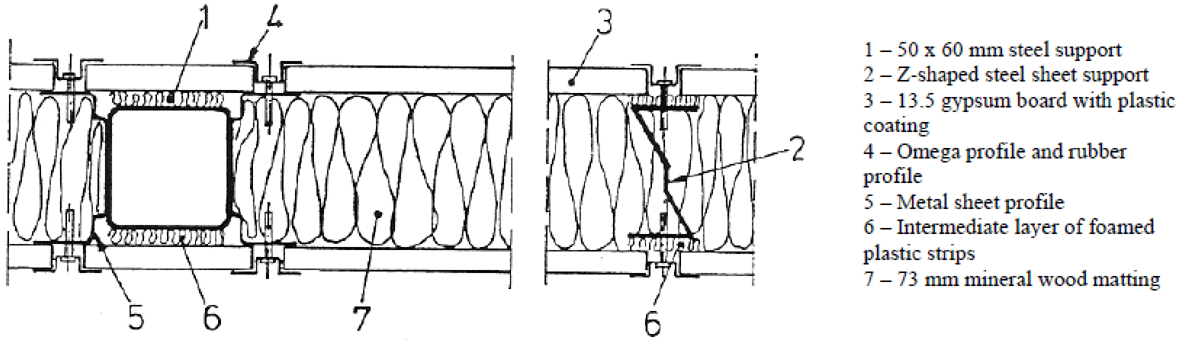


Figure 3. Some materials used to attenuate noise level in Lightweight board walls (Bragança and Patrício ,2004).

2.5 Noise control and attenuation

In residential areas, noise may stem from mechanical devices, like heat pumps, ventilation systems, and traffic. Moreover, voices, music, and other kinds of sounds are generated by neighbors, such as lawnmowers, vacuum cleaners, and other household equipment (TV, washing machines, etc. Aberrant social behavior is a well-recognized noise problem in multi-family dwellings (Doda, 2017).

A noise problem starts with a noise source such as a loudspeaker or live music. The noise is transmitted through a path and then arrives at the receiver. The noise will be perceived as a problem when the noise is as high as to be a nuisance to the receiver. To reduce environmental noise, there are three methods:

A. Control at noise sources: It is often a primary consideration to reduce noise at its source, by creating quieter working methods or technology. For example, noise from motor vehicles including motorcycles is under control and should meet internationally recognized noise emission standards. A noise enclosure for reducing loudspeaker and live music levels in residential areas by creating a legally binding situation just the noise has not gone over limited standards.

B. Noise reduction at the transmission path: An obvious way of reducing noise is to separate the sources of noise from noise-sensitive uses. This is however often not practical in a compact and high-rise city to rely only on distance attenuation to cut down the noise such as in the case of tackling road traffic noise. Proper land use planning to avoid busy highways cutting across residential developments or coming too close to sensitive uses; locating noise tolerant uses to screen noise-sensitive developments and a combination of the different noise attenuation means can often pre-empt noise problems at the design stage. Options to avoid or minimize noise, say, through adopting alternative transport such as railway, pedestrian links, cycling paths, and underground roads can also be considered at the early planning stage.

C. Protection at the receiver end: By arranging noise-sensitive uses such as bedrooms facing away from the noise sources, the impact of noise on the receiver can be reduced. While acoustic insulation by good glazing can cut down noise, its application for residential buildings practically deprives the receiver of an "open-window" lifestyle and requires the provision of air conditioning due to the warm and humid climate. As such, it is often used as a last resort only, (Cunniff, 1977).

3. Methodology

Two multi-story residential buildings will be selected from different dwelling projects in Erbil MRF Towers & Park View), as the two most famous residential towers in the city. Three apartments from each community will be selected as case studies representing the common condition in the majority of the residential units for each tower and should be in both communities with similar sizes or categories. The acoustic analysis will be carried out, and the comparison between them will be approached to find the advantages and disadvantages in each of them in terms of building acoustic performance. The literature will be reviewed and the theoretical analyses will be carried out based on similar studies related to the subject of the current study in order to formulate initial indicators regarding the current study.

The quantitative approach will be conducted through direct observation of the case studies, and getting direct measurements of the dB level inside and outside the buildings. Inside the building will include; 1) The sound from corridors or neighboring spaces; 2) the sound from people and their activities inside the apartment; Outside the building will include the measurement of the sound of cars, machines, etc. In addition to this, analysis of the documentary and cad files will be approached in order to evaluate the apartments acoustically, by; analyzing the organization of the spaces in the buildings; the availability of noise sources like roads, factories, schools, etc. The availability of noise attenuation sources will be investigated too, such as waterfalls, fountains, trees, walls, and building construction materials. The results will be analyzed according to the obtained data.

On another side, the qualitative approach will be conducted through a questionnaire to the occupants, asking them about their evaluation of the acoustic comfort. Likert's scale will be conducted to evaluate acoustic comfort, ranging from; Very Noisy (1), Noisy (2), average (3), Quiet (4), and Very Quiet (5), and the result will be extrapolated. A comparative analysis between the quantitative and qualitative results will be carried out, and the results will be extrapolated. See Figure '4'.

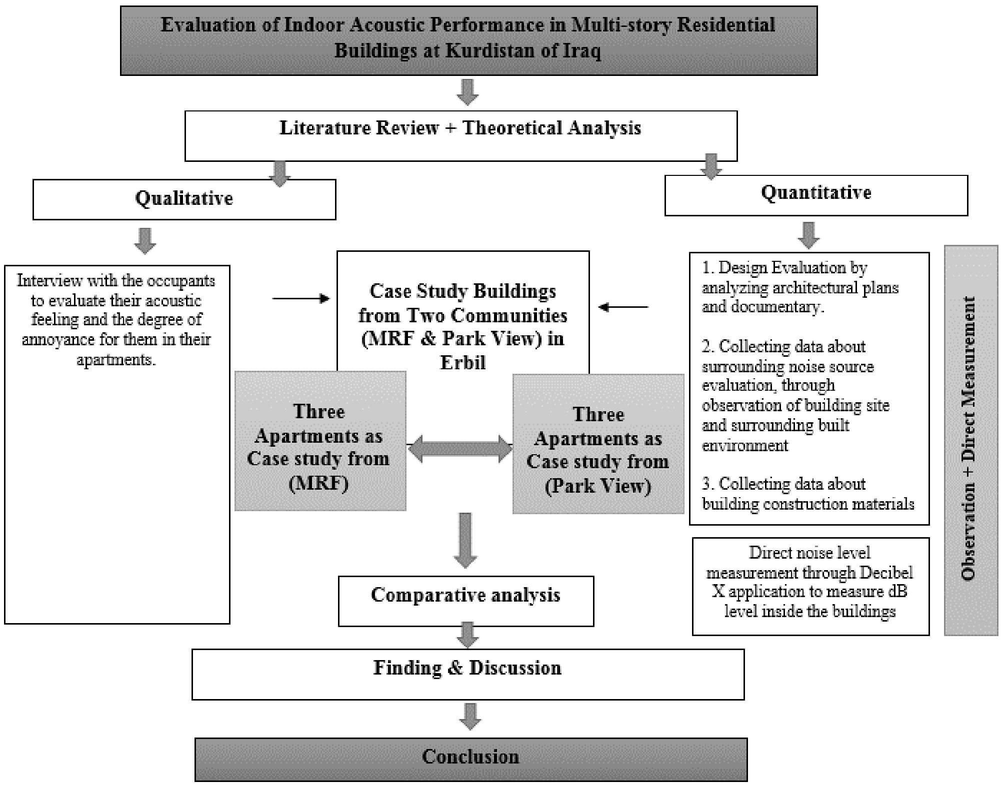


Figure 4. Methodology Framework.

3.1 Case Studies

3.1.1 MRF Towers Community in Erbil

The project is located in Erbil city, in the Kurdistan region of Iraq. MRF Towers are positioned between two main streets, 100m, and 40 m, between Empire towers and English Village. The project contains eleven towers, with 20 floors for each tower. See Figure 5-a'. Tower (5) has been selected, each floor consisting of four flats, and three flats (1, 2, 3), have been chosen on the 9th floor to be analyzed, as seen in Figure '5-b'.

(a). MRF Towers in Erbil.

(b). The location of the selected tower, and the flats.

Figure 5. MRF Towers.

The total area of each flat is 165 m^2, and contains one guest room and two Bath and toilets, one master bedroom, and two other smaller bedrooms, as seen in Figure ‘6’.

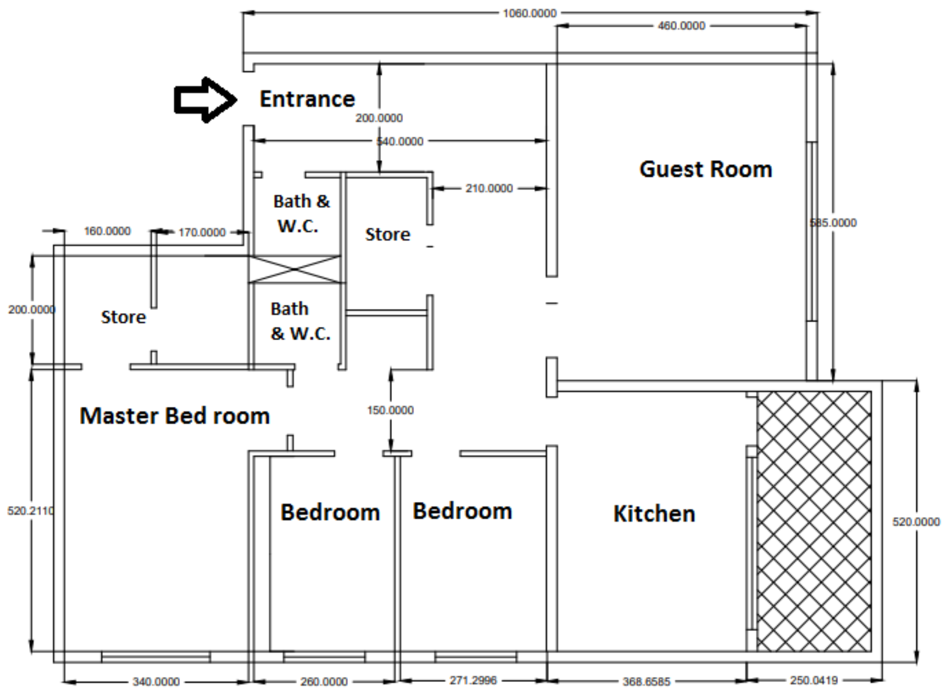


Figure 6. Plan of the flats in MRF Towers.

3.1.2 Park View Community in Erbil

Park View in Erbil contains high rises with 18-story considers one of the most prestigious residential projects. See Figure '7'.

Figure 7. Park View Community Buildings in Erbil.

The 50,000 square meters gated community is part of the Salahaddin Holdings' venture, which offers mid-size to extra-large apartments, ranging from 135 to 310 m2. Type -5 flats have been selected with 158 m2, without balconies area, and 183 m2 with balconies. Each floor contains 4 flats. Three flats on floor 10, have been selected and all of them were type-5. The flat consist of a guest room plus other three rooms, one master bedroom, and a small bedroom, as well as a living room, which some flats used as a bedroom. The flats' inner spaces area is illustrated in Table '3'.

Table 3. The area of the rooms and interior space for selected flats Type-5.

No.	Space function	Area (m^2)
1	Living Room	39.00
2	Kitchen	16.00
3	Living room or (Bedroom)	14.00
4	Bath room	5.50
5	Master Bed Room	20.00
6	Bath room	6.00
7	Walk in. Closet	4.00
8	Bed Room	17.00
9	Balcony1	19.00
10	Balcony 2	6.00
11	W.C.	3.00
12	Entrance hall	9.50
13	Corridor	7.50
	Total Area of the Flat Type-5	183.00

Figure '8', shows the plan of the Type-5 flats, and the spatial distribution, as well as the distribution of each flat within the floor.

Figure 8. Park view flat "Type-5" plan.

4. ANALYSIS & DISCUSSION

This part will demonstrate the noise measurements, observation, and documentary analysis, starting with identifying the main outer source for each case study.

4.1 Analysis of the First Case study MRF Towers.

The analysis of the case study has been arranged as follows:

A. Site analysis: The analysis of the site for the first case study demonstrated that the outer noise sources are from, traffic, and cars, because the buildings are surrounded by roads and streets. See Figure '9'.

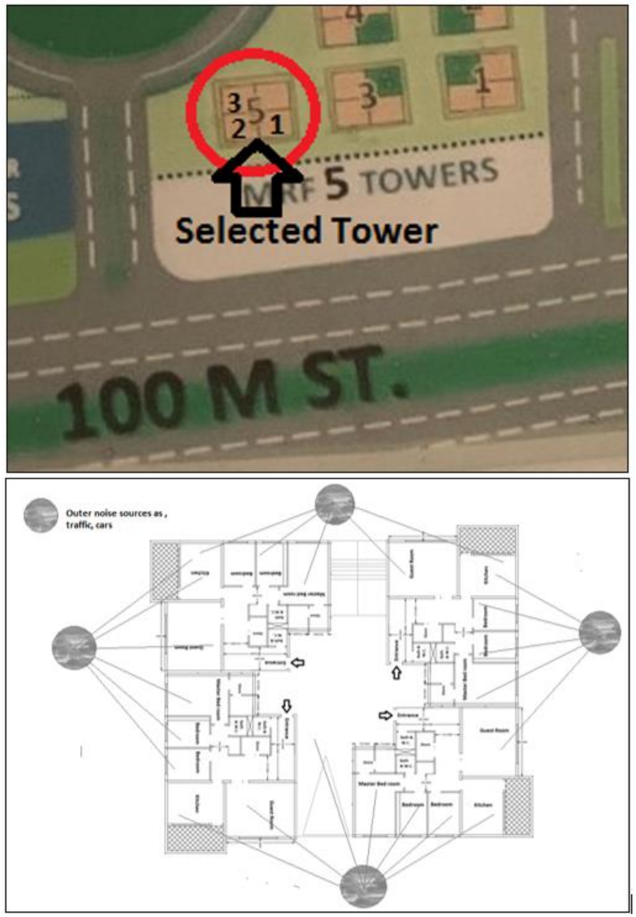


Figure 9. Outer noise source for MRF Towers.

B. Outer and Inner sound sources (Direct sound Transmission): The noisy zones inside the building plus the outer noise sources' effects on the building have been identified and their effects on the quiet zones are shown. The noise from the kitchen, entrance, and bathrooms, are inner noise sources inside the flat. See Figure ‘10’.

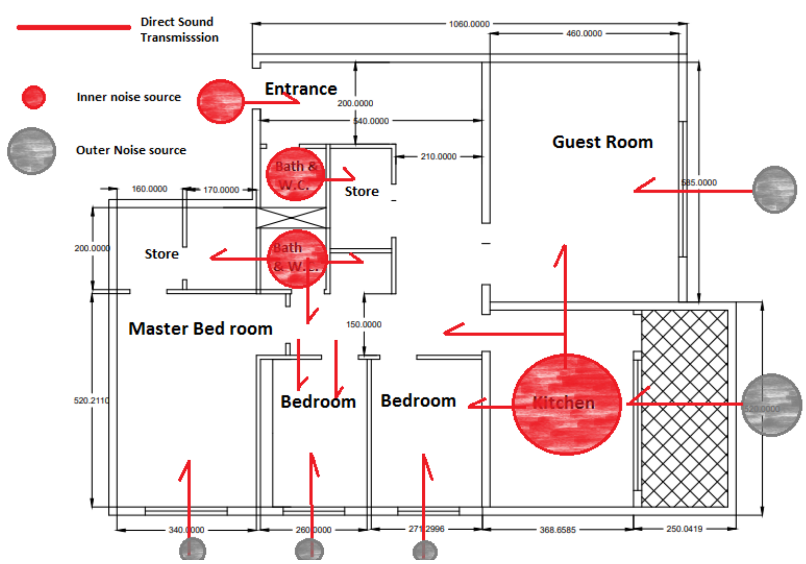


Figure 10. Noise sources (outer and inner) effects on the noise level in the inner spaces.

Figure 10, above demonstrates the analysis of direct sound transmission through the joints or openings or through the walls and windows. The quiet zones like bedrooms have been affected by outer noise sources by facing outside traffic and car sounds, and inner noise sources like bathroom and kitchen.

C. Indirect flanking transmission or structure airborne: It investigates the effects of the neighbors through knocking, vibration, on adjacent walls (like in guest room), or falling objects on the ground on upper neighbors. Moreover, outside the staircase, and adjacent rooms, in addition to mechanical or electrical devices inside the home itself will create indirect flanking transmission of noise. The most place affected by indirect sound transmission or structure airborne is guest rooms and Master bedrooms, as well as the kitchen, as shown in Figure '11'.

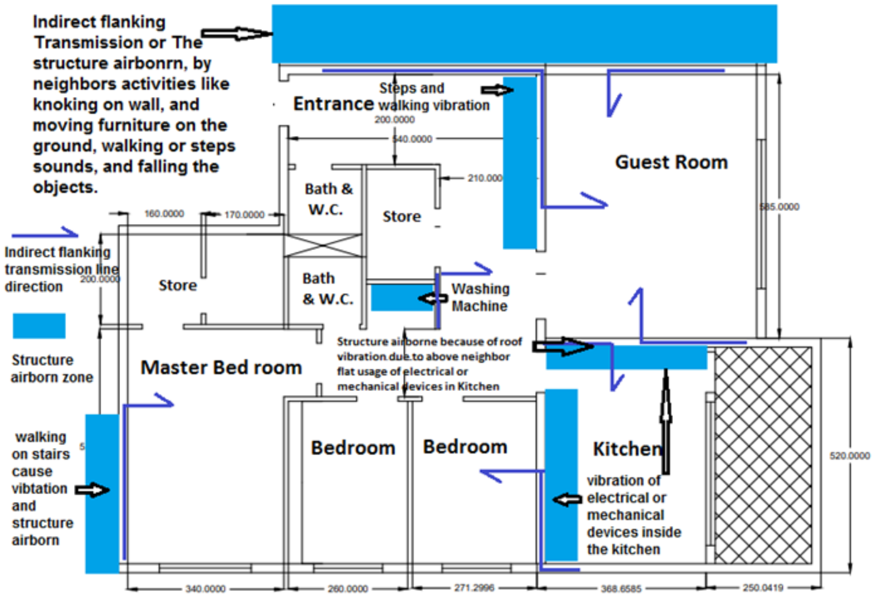


Figure 11. The in-direction flanking transmission of noise or structure airborne by vibration.

D. Direct measurement of dB level inside the apartments: It has been carried out in order to evaluate the noise level. The iPhone application (Decibel X) has been employed for this purpose, and all the measurements have been taken during day time. The measurements have been taken in day times. See Figure '12'.

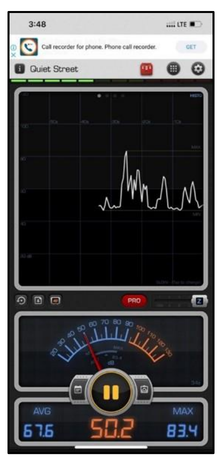


Figure 12. IPhone application "Decibel X", for measuring of dB level.

Noise level through dB measurement inside three apartments has been carried out in bedrooms, guest rooms, and kitchens, in addition to the corridors and outside of the buildings from four directions. See Figure '13'.

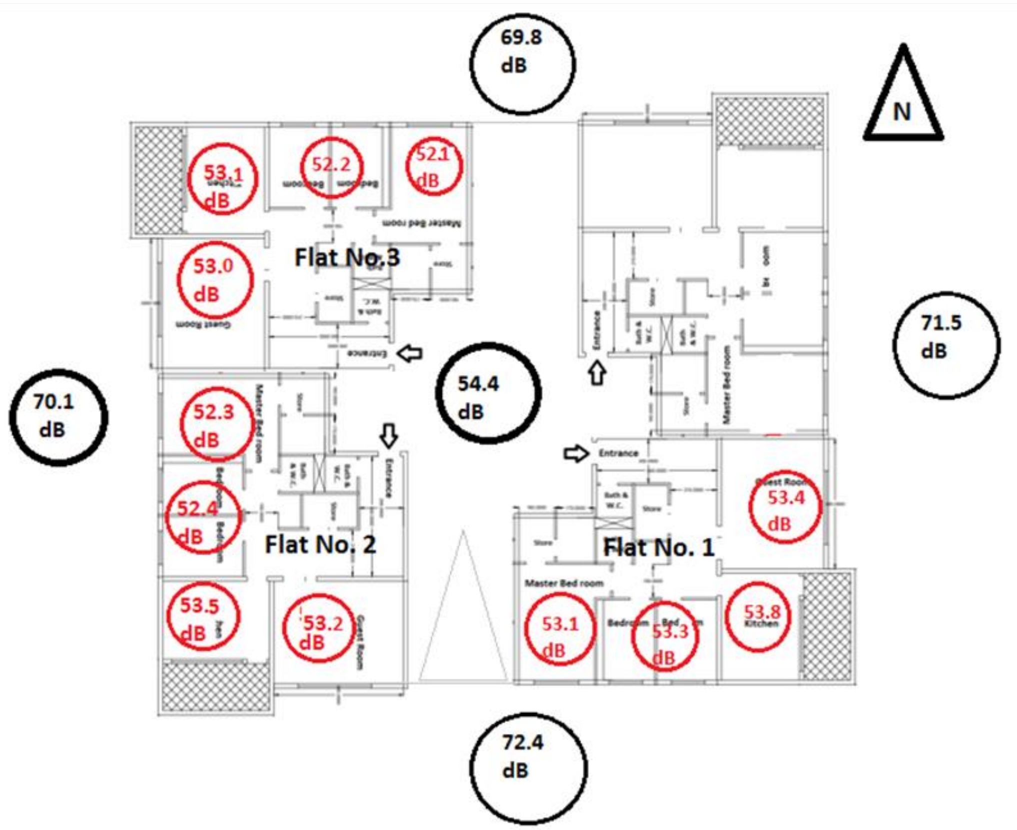


Figure 13. The dB level inside and outside of the First case study buildings- MRF Towers.

The dB level measurement demonstrated that the rooms that face the 100-meter street, are getting more noise than other parts. While the measurements demonstrated that the master bedrooms are the quietest rooms in all the buildings, and the reason is that they are not containing many devices such as a TV, and have fewer activities than other parts. Other small bedrooms are noisier than the master bedroom because they are adjacent to Kitchen. The results demonstrate that the noise level, is high inside bedrooms, and guest rooms, and acceptable for kitchens inside residential buildings dB which is acceptable up to 55 dB as per international standards, (WHO, 1999). See Table '4'.

Table 4. dB level inside the flats in MRF Towers, measured by Decibel X application.

No.	Flat no.	dB level in Guest room	dB level in Master Bed room	dB level in B. room 1&2	dB level in Kitchen
1	Flat 1	53.4	53.1	53.3	53.8
2	Flat 2	53.2	52.3	52.3	53.5
3	Flat 3	53.0	52.1	52.2	53.1

The noise level in flat no.1 is higher compared with the other two flats and the lower noise level is in flat no. 3, and the reason is returning to the relationship between these flats' location with the main roads, where flat no. (1), is located on the corner of two roads, while flat no. (2), is located on the (100-meter street), and flat no. (3), is located back of the 100-meter street, on the lateral road. Therefore, this flat is recording lower noise levels. The kitchen was recorded as the noisiest place in all the flats, and guest rooms came second, while master bedrooms were always quieter than other parts. Bedrooms 1 &2 demonstrated higher noise levels than the master bedroom. The reason behind this was the adjacent of these rooms to the kitchen, which let airborne and structure-borne sounds, through direct transmission and indirect flanking transmission occur between the kitchen and these bedrooms. Furthermore, the corridor among the flats recorded 54.4 dB, which is higher than the noise level inside the flats, because it contained services like lifts and staircases, and more movement as a transmission part in the building, and all of that increased the noise level. See Figure '12'.

4.2 Analysis of the second Case study Park View

A. Site analysis: the site analysis for the place of Park view showed that it is located close to a 100-meter street, which causes traffic and car noise, on another side the case study building is close to the park and kids' entertainment place. See Figure '14'.

Figure 14. Outer noise source for Park View towers.

B. Outer and Inner sound sources (Direct sound Transmission): The noise outside and inside the building has been analyzed, the noise from the kitchen, entrance, and bathrooms, are inner noise sources inside the flat. While, traffic, cars, car parking, streets, and entertainment area for kind in the parking area are outer sound sources and their effects through (direct sound transmission) on the quiet zones shown in Figure '15'.

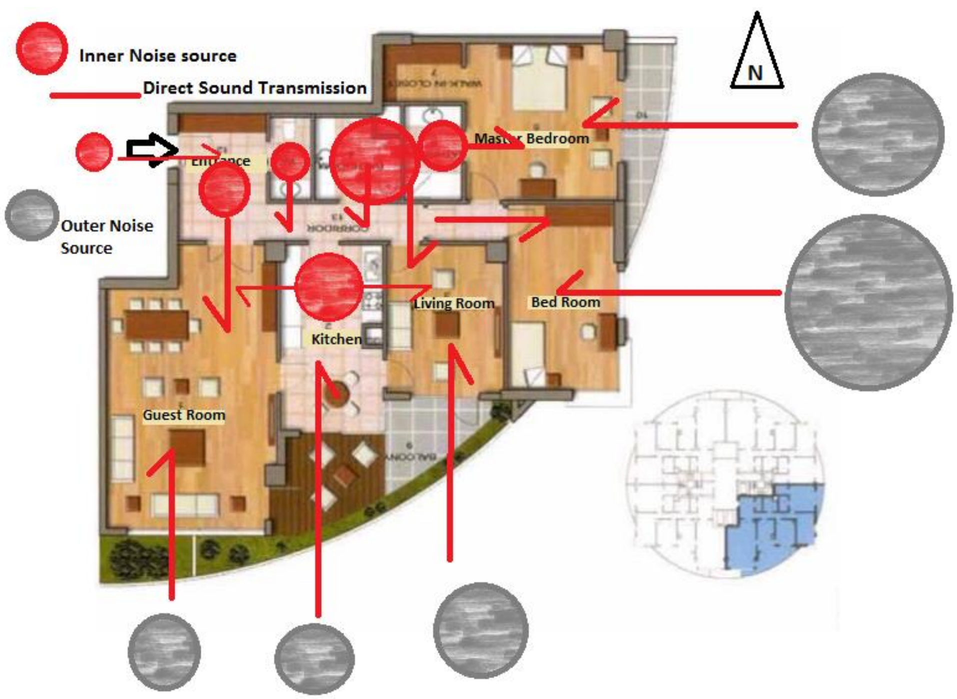


Figure 15. Noise sources (outer and inner) effects on the noise level in the inner spaces.

C. Indirect flanking transmission or structure airborne: the indirect flanking sound transmission results from the adjacent or above neighbors through walking on the floor, knocking on the ground by the upper neighbors, or adjacent neighbor activity by vibrating the walls because of human activities or electrical or mechanical instruments usage. Moreover, outside services like (staircases and lifts) adjacent rooms. In addition to this, the mechanical or electrical devices inside the home itself will create indirect flanking transmission of noise, especially from the kitchen and bathrooms. The most place affected by indirect sound transmission or structure airborne is guest rooms and Master bedrooms, as well as the kitchen, as shown in Figure '16'.

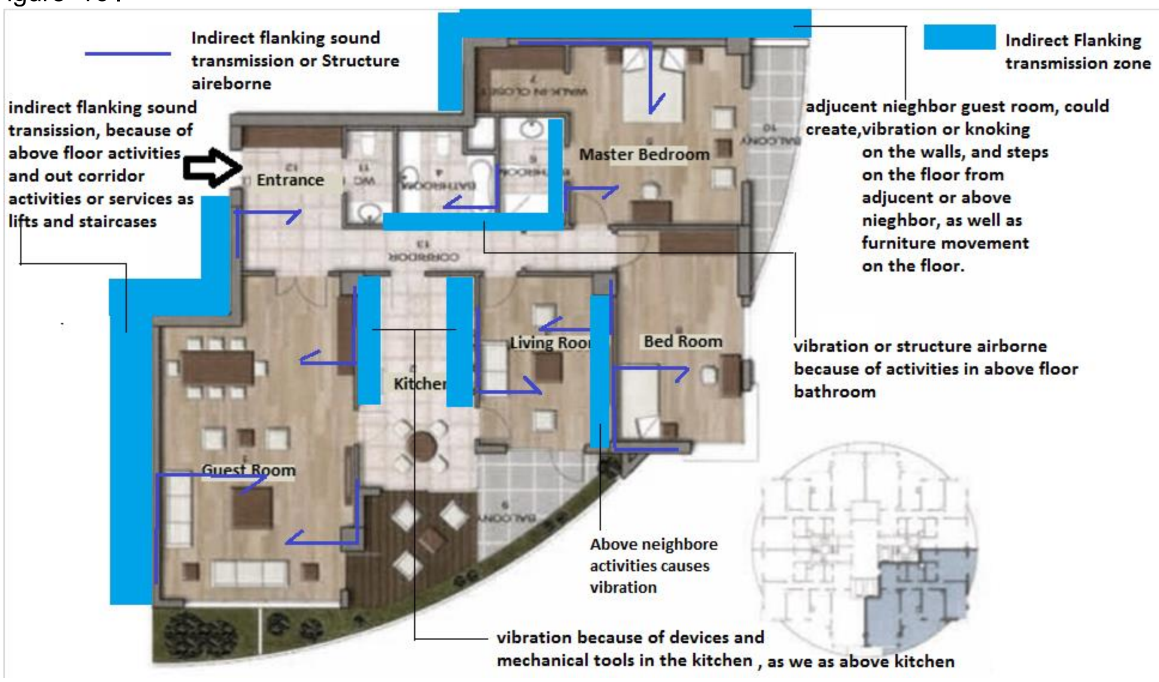


Figure 16. The in direction flanking transmission of noise or structure airborne by vibration in Park View buildings.

D. Direct measurement of dB level inside the apartments: the measurements of dB level inside and outside the buildings in three flats and outer corridors have been carried out in the same way, explained for MRF Tower in the first case study. See Figure '17'.

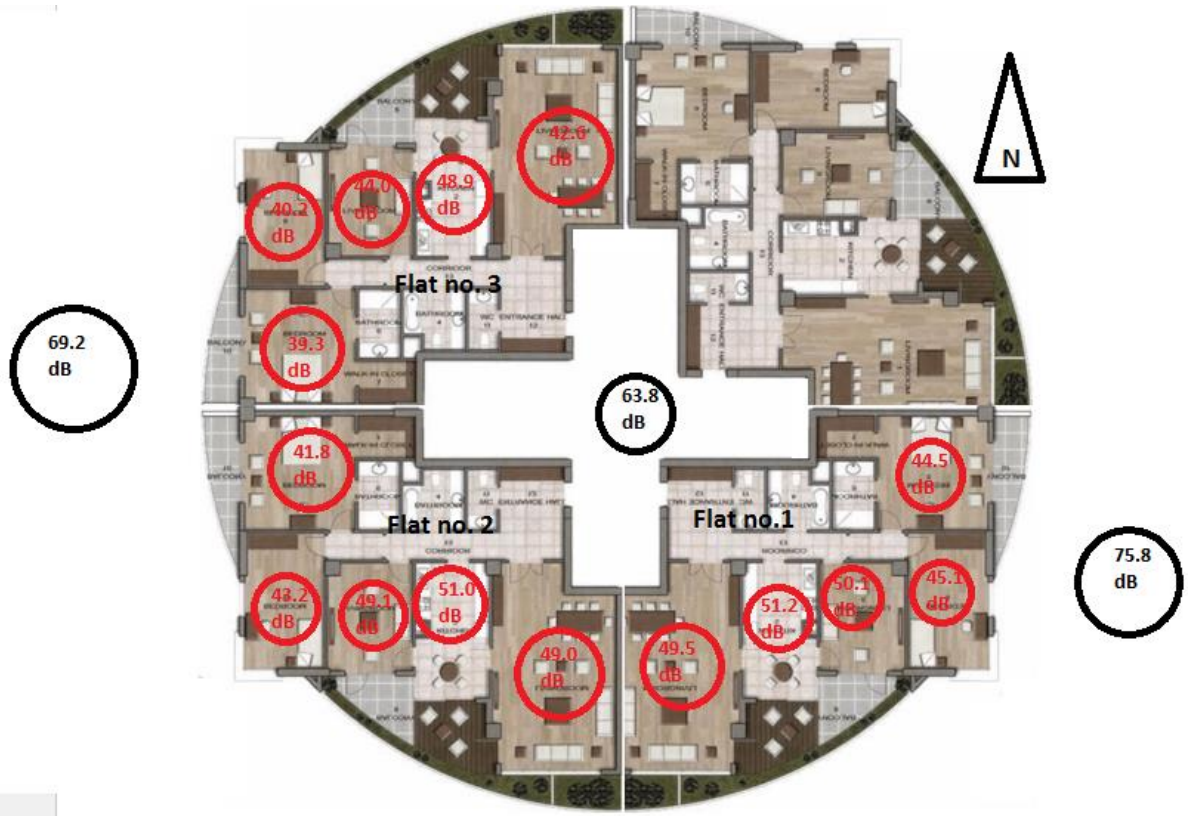


Figure 17. (dB) level inside and outside of the Second case study buildings- Park View.

The measurement of the dB level in the three flats at Park View buildings showed that the outside noise level is high and reaches almost 76 dB. The corridor area inside the building demonstrated a 63.8 dB level, which is relatively high. While the noise level inside the flats dropped more than 20 dB in some spaces. This indicates that the insulation material of walls and roofs is good. However, flat number (1) was noisier than the other two flats because it is closer to the street than the other two. The second flat demonstrated a slightly lower noise level than the first flat because it is not very close to the street. The third flat which is facing the inner part of the Park View community, and the kids' entertainment park, hence it demonstrated lower noise spaces. Commonly, master bedrooms did not achieve acoustic comfort level according to the standards, which registered 44.5, 41.8, and 39.9 dB for flats 1, 2, and 3, respectively, and the same thing for the smaller bedrooms. Guests and living rooms did not meet the acoustic comfort as per the standards, which registered above 35 dB, and only kitchens were as per the standards, where they registered below 55 dB. See Table '5'.

Table 5. dB level inside the flats in Park View Buildings, measured by Decibel X application.

No.	Flat no.	dB level in Guest room	dB level in Master Bed room	dB level in B. room 1	dB level in Living room	dB level in Kitchen
1	Flat 1	49.5	44.5	45.1	50.1	51.2
2	Flat 2	49.0	41.8	43.2	49.1	51.0
3	Flat 3	42.6	39.3	40.2	44.0	48.9

The questionnaire applied in both case studies and the occupants of the flats were asked about, how much are they bothered by the noise sources. The questionnaire forms were distributed among 16 occupants (nine in Park View, and nine in MRF Towers), as the occupants of the three flats in each building. The questionnaire demonstrated that 100% of the occupants are living in the flats between 1 to 5 years, and flat members were 100% between 3-5 people. The results have been manipulated by Likert's scale and the results demonstrated that the occupants are suffering from noise sources but with fewer condition in the flats at Park View Building, as seen in Table '6'.

Table 6. The results of the questionnaire after evaluating the occupants' answers by Likert's method.

No.	Item	Park View	MRF Towers
1	**How much are bothering**: Neighbors; daily living, e.g., people talking, audio, TV through the walls.	Quiet	Average
2	**How much are bothering**: Neighbors; footstep noise, i.e., you hear when they walk on the floor.	Average	Noisy
3	**How much are bothering**: Neighbors; rattling or tinkling noise from your own furniture when neighbors move on the floor above you.	Noisy	Very Noisy
4	**How much are bothering**: Staircases, access balconies etc.; people talking, doors being closed.	Quiet	Average
5	**How much are bothering**: Water installations; plumbing, using or flushing WC, shower.	Quiet	Average
6	**How much are bothering**: Traffic (cars, buses, trucks, trains or aircraft); heard indoors with windows closed.	Noisy	Very Noisy

The results show that the occupants in Park View buildings are more comfortable acoustically than in MRF Towers buildings, and this is because of the quality of building materials that are used in Park View, compared with the MRF Tower. However, both buildings did not achieve acoustical comfort as per standards inside the flats.

5. Conclusion

According to the analysis of the obtained data through; direct measurement, document and plans analysis, and questionnaire, the study found the following; the study shows highly indicates that there are serious noise problems in multi-story residential buildings in Erbil, which affect acoustic comfort of occupants. There exist particular problems with impact noise types from neighbors, which include a high degree of low-frequency content. The measurement results demonstrated that the Park View buildings are more comfortable than MRF Towers, where despite the noise level outside of the flats registered higher in the site of Park View, the noise level in the majority, of spaces is lower and, in some places, reaches 10 dB, as seen in Tables '4 &5'. This indicates that the insulation materials in the construction of Park View are better than what has been applied in MRF Towers. The results demonstrated that the occupants in Park View buildings, are more comfortable acoustically than in MRF Towers buildings, and this is because of the quality of building materials that are used in Park View, compared with the MRF Tower. This is indicating that the salutogenic design was approached more successfully in Park View than in MRF Tower. The location of the Kitchen in the Park View flats is more successful than the one in MRF Tower because kitchens are the source of noise inside the residential buildings. See Figures 6 & 8. Therefore, in Park view flats it is between the living room and guest room, while in MRF Towers it is between the guest room and bedroom, and this will increase direct and indirect sound transmission to the bedroom which should be in a quiet zone. Moreover, the cylindrical form of Park View Tower is helping to mitigate the noise level comparing it with the rectangular shape of the MRF Towers. Finally, the study concluded that the materials of the building construction is a key role in the attenuation of the noise levels in multi-story residential buildings, in addition to space organization, and buildings form.

Acknowledgements

The author wishes to acknowledge the editor and reviewers in the Journal of Salutogenic Architecture for their constructive feedback during the review process.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The Author(s) declare(s) that there is no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Reference

Antonovsky, A. (1996). The salutogenic model as a theory to guide health promotion. *Health Promotion International*, 11(1), 11–18. https://doi.org/10.1093/heapro/11.1.11

A Guide to New York City's Noise Code. (2007). *Understanding the most common sources of noise in the city*. New York, United States: New York City Department of Environmental Protection Bureau of Environmental Compliance.

Bragança, L., & Patrício, J. (2004). Case Study: Comparison between the Acoustic Performance of a Mixed Building Technology Building and a Conventional Building. *Building Acoustics*, 11(2), 145–156. https://doi.org/10.1260/1351010041494737

Berendt, R. D., Corliss, E., & Ojalvo, M. (1978). *QUIETING IN THE HOME*. Washington DC, United States: U.S. Environmental Protection Agency Office of Noise Abatement and Control.

Cambridge Dictionary. (2018). *Noise*. Retrieved from https://dictionary.cambridge.org/dictionary/english/noise

Claridge, S. (2007). *How Loud Is Too Loud: Decibel levels of common sounds*. Retrieved from https://www.hearingaidknow.com/how-loud-is-too-loud-decibel-levels-of-common-sounds

Doda, D. (2017). An Assessment of Noise Pollution in Addis Ababa: The Case of Bole Michael Community Area. *Master Thesis*, Addis Ababa University, Addis Ababa, Ethiopia.

Cremer, L., & Heckl, M. (1973). *Structure-borne sound: structural vibrations and sound radiation at audio frequencies*. Berlin, Germany: Springer-Verlag. https://doi.org/10.1007/978-3-662-10118-6

Cunniff, P. F. (1977). *Environmental noise pollution*. John Wilay, New York.

Golembiewski, J. (2022). Salutogenic Architecture. In M. B. Mittelmark et al. (Eds.), *The Handbook of Salutogenesis*, (pp. 259-274). Berlin, Germany: Springer Nature. https://doi.org/10.1007/978-3-030-79515-3_26

Hansen, C. H. (2000). *Fundamentals of Acoustics*. University of Adelaide, Australia. Retrieved from https://www.archtoolbox.com/representation/architectural-concepts/architectural-acoustics-acceptable-room-levels.html

Komla, A. D. (2012). Evaluation of Noise Levels of Corn Mills in Ablekuma North Sub-Metro, Accra. *Master Thesis*, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Katz, R. A. (2010). The Decibel Report: Acoustic Sound Measurement, Modeling, and the Effects of Sonar on Marine Mammals. *NUWC-NPT Technical Report*. Newport, Rhode Island: Naval Undersea Warfare Center Division Newport, Rhode Island.

Meisser, M. (1978). *The Practice of Acoustics in the Building*. Paris, France: Editions Eyrolles.

Mittelmark, M.B., & Bauer, G.F. (2016). The Meanings of Salutogenesis. In M. B. Mittelmark et al. (Eds.), *The Handbook of Salutogenesis*, (pp. 259-274). Berlin, Germany: Springer. https://doi.org/10.1007/978-3-319-04600-6_2

Muhy Al-Din, S.S., Kuzovic, D., & Iranfar, M. (2017). Renewable Energy Strategies to Overcome Power Shortage in Kurdistan Region of Iraq. *Industrija*, 45(2), 7-21. https://doi.org/10.5937/industrija45-12770

Oxford Dictionary. (2018). *Sound*. Retrieved from https://en.oxforddictionaries.com/definition/sound

Shawkat, L. W., Muhy Al-Din, S. S., & Kuzovic, D. (2018). Opportunities for Practicing Sustainable Building Construction in Kurdistan Region, Iraq. *Journal of Contemporary Urban Affairs*, 2(1), 69-101. https://doi.org/10.25034/ijcua.2018.3665