JES, Vol. 52, No. 2, March 2024 DOI: 10.21608/jesaun.2023.236434.1260 Part E: Architectural Engineering

Journal of
Engineering Sciences
Faculty of Engineering
Assiut University

مجلة
العلوم الهندسية
كلية الهندسة
جامعة أسيوط

journal homepage: http://jesaun.journals.ekb.eg

The mechanisms for successful sound design in educational spaces to achieve acoustic comfort and their impact on academic efficiency: (The study of auditoriums in universities)

Received 14 September 2023; Revised 16 November 2023; Accepted 10 December 2023

Mohamed Mahmoud Hassan Abd Elregal [1]

Keywords
Underwater Object Detection, Computer Vision, Remotely Operated Vehicles (ROVs), Metal Object Recognition

Abstract: Architects prioritize designing different buildings to maximize the utilization of natural resources such as natural lighting, natural ventilation, and renewable energy. However, some individuals overlook the focus on architectural acoustics, which deals with controlling sound transmission from the outside to the inside or improving sound distribution within spaces, and the negative impact that improper design can have on human health. According to The World Health Organization (WHO) last updated its guidelines on environmental noise in 2018. These guidelines provide recommendations and standards for addressing the impact of noise on human health and well-being. Affirming that noise has negative effects and serious health consequences, including hearing loss, cardiovascular diseases, and a decline in physical and mental performance. Therefore, the research addresses a scientific methodology that assists architects in designing spaces that achieve sound comfort, with a particular focus on educational spaces, including a case study on lecture halls in universities...

1. Introduction

Public audition rooms, in terms of natural sound propagation, have been a subject of ongoing discussion and research in the field. Unless the sound field is achieved through electrical-acoustic methods, the quality of audition in these rooms can only be enhanced through appropriate acoustic design that takes into consideration the room's geometry and sound treatment. [1]

[1] Lecturer, Department of Architecture, Modern Academy for Engineering and Technology, Cairo, Egypt.
Arch_mohamedmahmoud@yahoo.com

https://doi.org/ 10.21608/jesaun.2023.236434.1260
This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

The successful acoustic design of educational spaces is of utmost importance to attain sound comfort. This necessitates a comprehensive examination of the users' requirements, as well as external and architectural factors, including the types of noise that impact the buildings, both from external and internal sources The issue of environmental noise poses a significant challenge in Egypt. Findings from noise measurements conducted by "The National Network for Noise Level Measurement in Greater Cairo" revealed that in most of the examined areas, noise levels exceeded the permissible standards outlined in the Environmental Law and its corresponding executive regulations (Egypt State of the Environment report, 2010) [٢]. Anticipating external noise levels through site analysis and establishing the building's performance requirements via simulation programs are essential steps. Subsequently, materials are chosen in collaboration with architectural engineers after evaluating their characteristics and their capacity to isolate or impede sound transmission, while also determining their contribution to enhancing the design. A variety of available materials can be employed to achieve sound comfort and mitigate issues such as echo and repetitive reverberation. It is essential to implement a sound design tailored to the specific circumstances from the inception of a building project and to incorporate acoustic treatment measures to enhance acoustic comfort, even in existing structures. After conducting the acoustic measurements and analyzing the data, it was found that the reverberation time did not fall within the standard range limits, necessitating several measures to enhance the hall's acoustics. The acoustic characteristics of the hall were determined in full compliance with European Union specifications.

2. The Main Objective of the Research

The research aims to redesign existing learning spaces by applying a methodology that ensures acoustic efficiency in those spaces. This is achieved by understanding the materials and treatments currently used, assessing their effectiveness, and then intervening through redesign to achieve acoustic comfort. This application specifically focuses on lecture halls in universities. The present paper deals with the study of the acoustic properties of the Lecture Hall belonging to the Faculty of Engineering in the Modern Academy building complex, and measures to improve the acoustic features of the hall are also considered.

3. Acoustics in buildings

The aims of sound control, also known as environmental acoustics, can be succinctly delineated as follows within an academic framework: Firstly, the primary objectives encompass the mitigation or elimination of noise and vibrations, commonly termed "noise control." Secondly, the secondary objective entails establishing optimal circumstances for the generation, propagation, and perception of desired sound, commonly known as "architectural acoustics **Fig. 1**. [3]

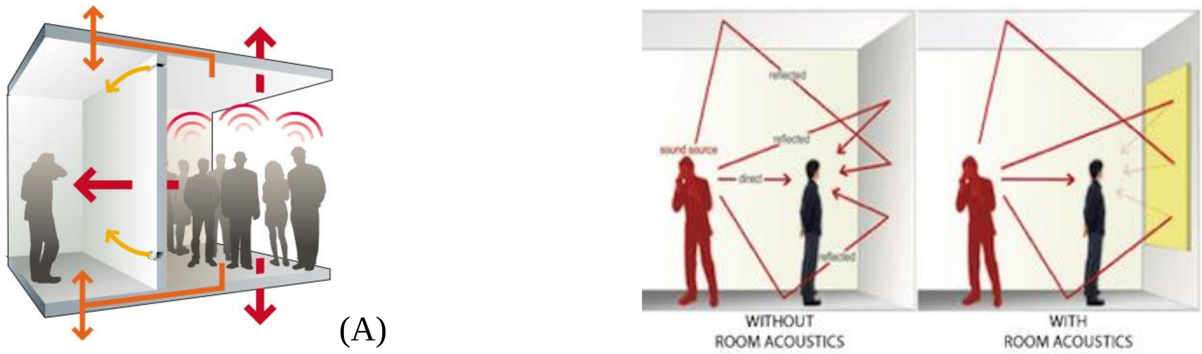


Fig.1. (A) and (B) Environmental acoustics in building source [4]

4. Noise in buildings

Definition of noise in buildings: unwanted sound that negatively affects people in several ways. It is a sound that is undesired by the human ear, and this is a personal sensation related to the psychological and physical state of the individual. It can be considered environmental harm stemming from technological advancements. Furthermore, it depends on several factors, including sound level and frequency. Sharp and unexpected sounds are the most disturbing are shown in **Fig. 2**. [5]

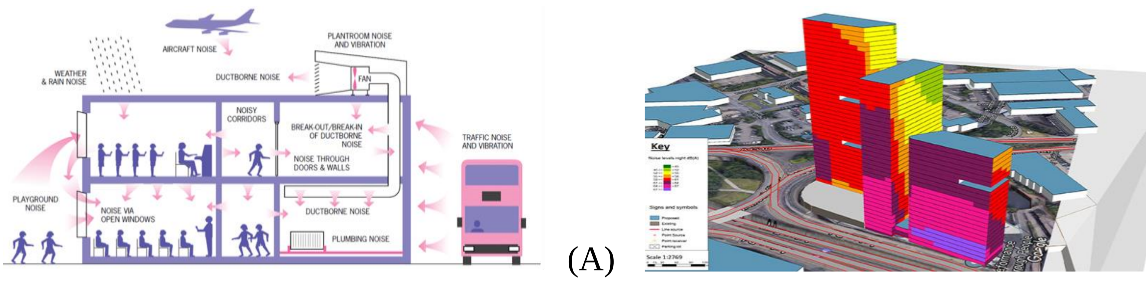


Fig. 2. (A) Noise in buildings (B) noise in building with simulation tools source [6]

4.1 Means of noise transmission in buildings:

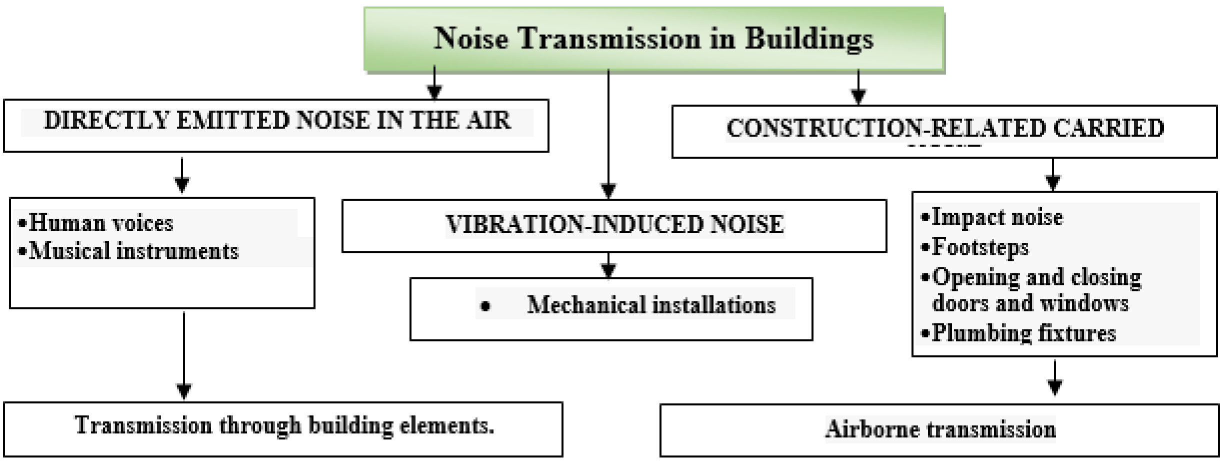


Fig. 3. Means of noise transmission in buildings source researcher

4.2 Treating noise in design buildings

4.2.1 Noise Control Areas (outdor) :

Controlling noise through the building's relationship with the surrounding environment. [7]

4.2.1.1*Use barriers and levels :*

It is used to control noise by creating an area known as the sound shadow, where wave propagation is reduced due to natural obstacles such as the terrain or the use of artificial sound barriers or natural barriers like trees are shown in **Fig. 4.** [٨]

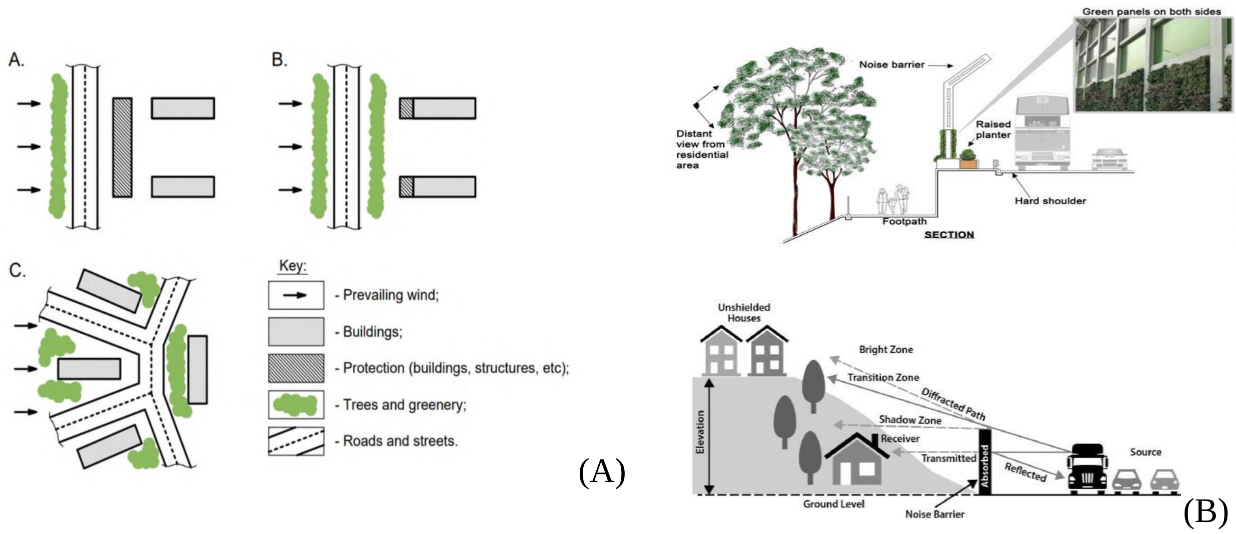


Fig. 4. (A) Using trees as a sound barrier (B) sound shadow with using level source [9]

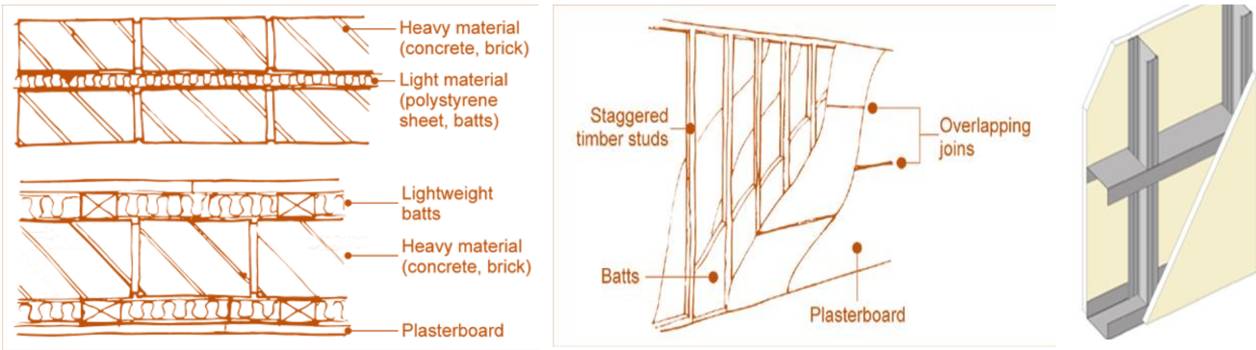
4.2.1.2*Facade Shape:*

The facade shape and its design have an impact on the transmission of sound within spaces, as do the materials used and their interaction with sound waves through reflection or absorption are shown in **Fig. 5.** [10]

Fig. 5. (A) and (B) and (C) Explain Facade Shape tratment for acoustices source [١١]

4.2.2.2 Internal wall (Partitions):

Partition walls can be used to divide the interior spaces of a building and have great sound isolation capabilities. They are typically constructed with multiple layers, including insulating core materials, and come in varying thicknesses are shown in **Fig. 6.** [12]

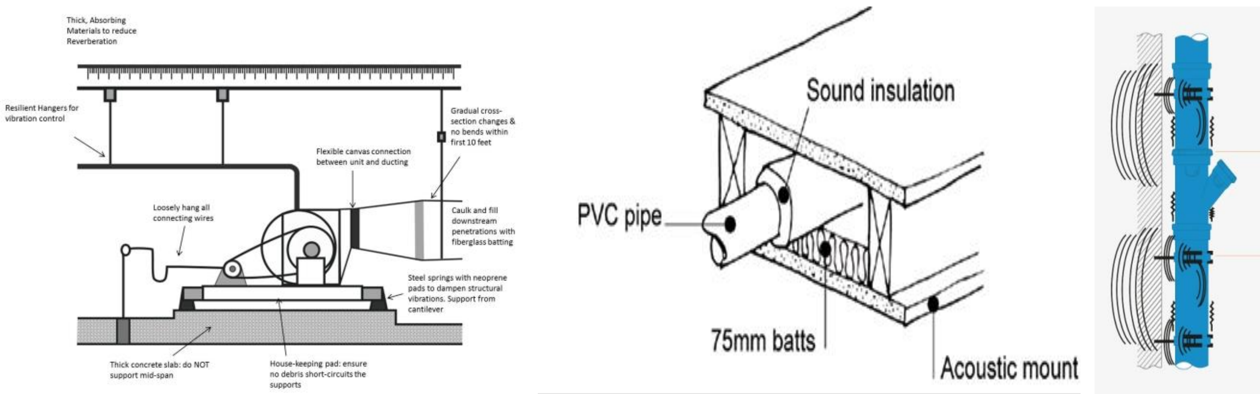


(A) (B) (C)

Fig. 6. (A) and (B) and (C) Explain Detail Internal wall (Partitions) source [13]

4.2.2.3 Services in building:

Treatments and materials that have the ability to absorb the noise generated by plumbing and mechanical installations are used in buildings are shown in **Fig. 7.** [14]



(A) (B) (C)

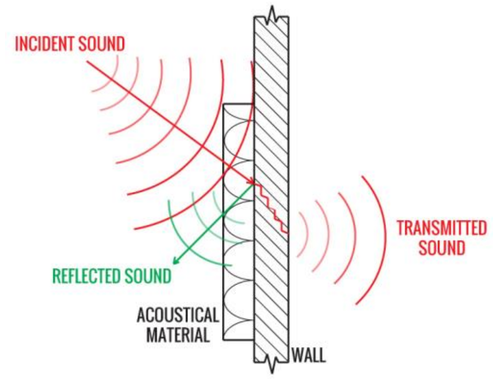
Fig. 7. (A) Using Treatment in celling (B) Using Treatment in floor
(c) Using Treatment in Sanitary pipes source [15]

5- Acoustics materials:

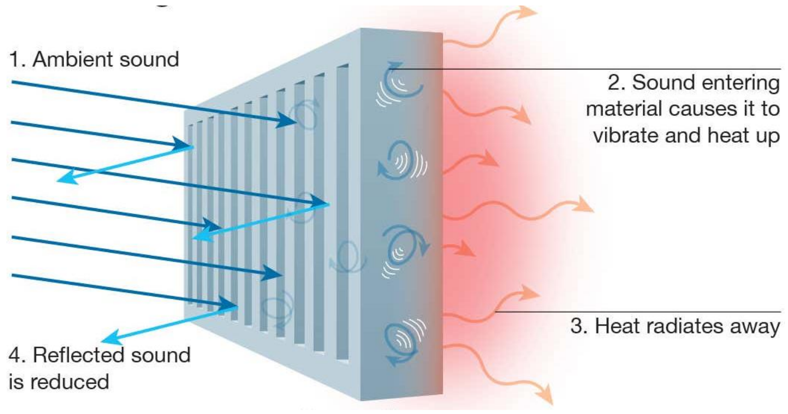
This refers to the use of specific materials to enhance sound in open environments or large spaces. These materials are used to reduce emitted high frequencies, echo propagation, and the incidence of frequencies within the space, thereby improving sound quality and the listening experience are shown in **Fig. 8.** [16]

5.1 Sound Insulation:

It is a collection of materials that aims to provide suitable insulation for a specific location with the purpose of reducing or mitigating the impact of disturbing noises generated by various sound sources are shown in **Fig. 9.** [18]

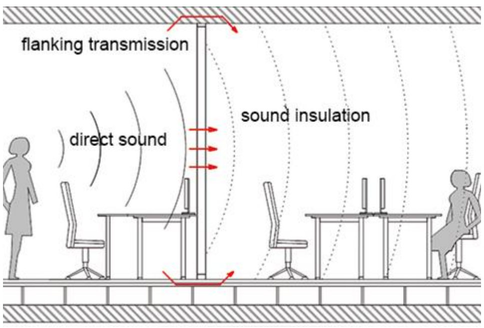


(A)

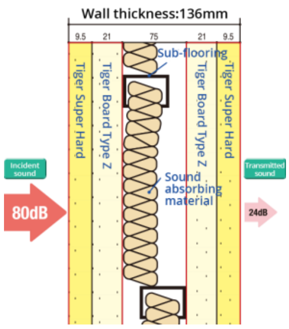


(B)

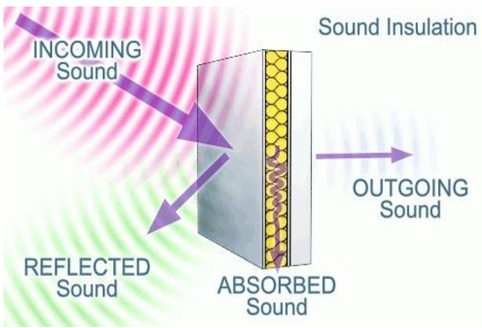
Fig. 8. (A) and (B) Explain Acoustic materials properties source [17]



(A)



(B)



(C)

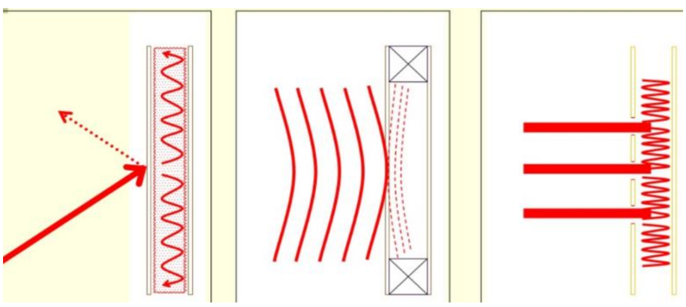
Fig. 9. (A) Sound Insulation effect (B) Sound Insulation materials (C) Sound Insulation materials behavior source [19]

5.2 Sound Absorption:

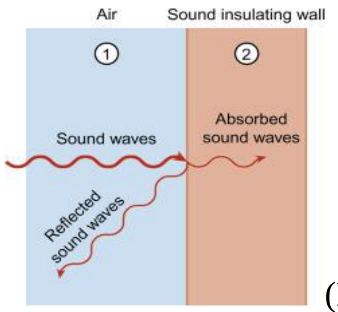
All materials have varying degrees of sound absorption, and each surface and element within A room will absorb sound to some extents are shown in **Fig. 10.**

Therefore:

- Soft and rigid materials, such as glass, have low sound wave absorption.
- Rough, lightweight, and porous materials tend to have higher sound wave absorption, such as carpets and curtains. [20]



(A)



(B)

Fig. 10. (A) and (B) Explain Acoustic materials Absorption behaviors source [21]

6. Methodology for Educational spaces to achieve Acoustic Comfort:

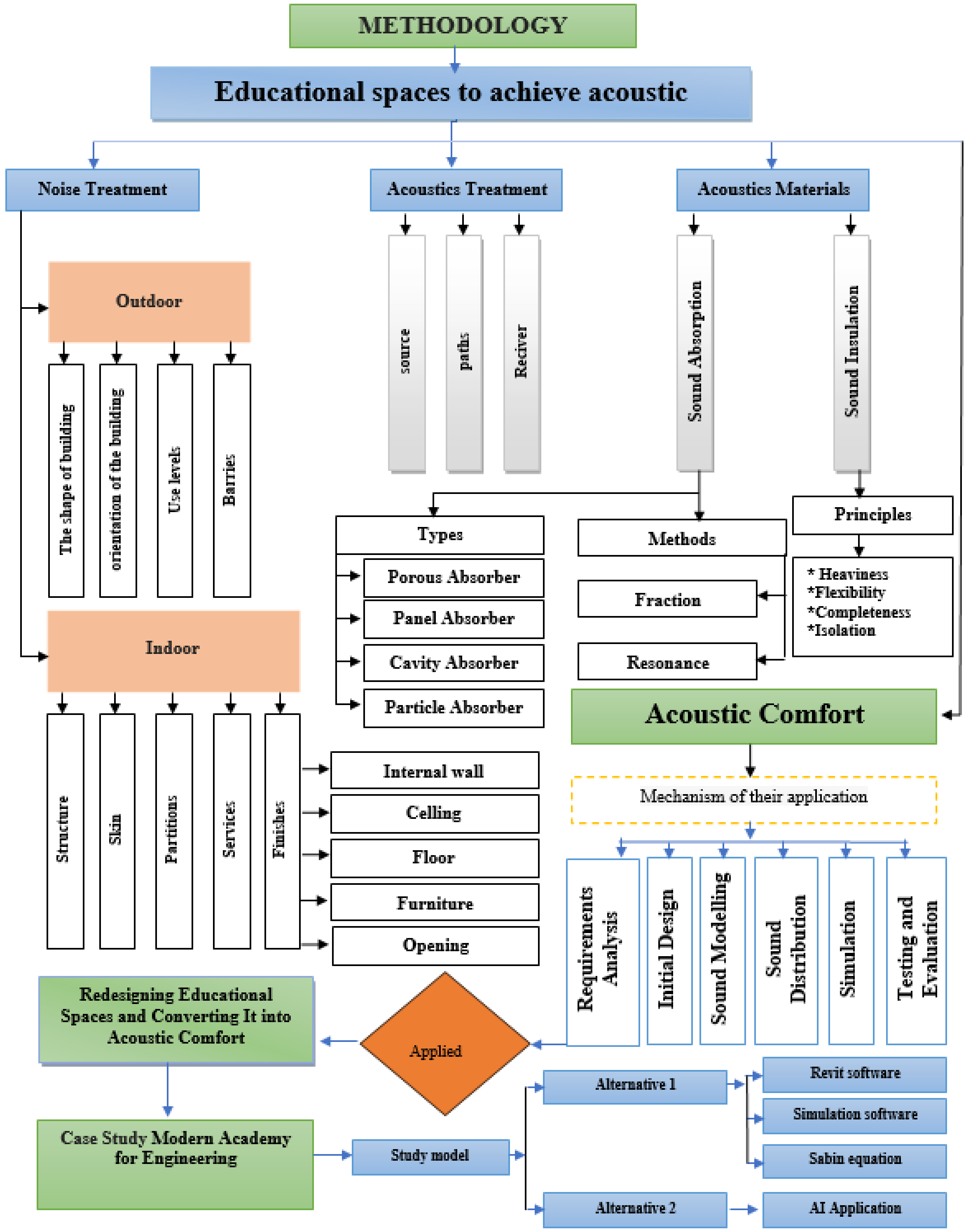


Fig. 11. Methodology For Educational spaces to achieve acoustic comfort source researcher

7. Experimental methodology:

The methodology is based on two main axes:

1. The alternative depends on applying the idea of educational buildings that achieve acoustic comfort and creating a design model that can be applied to existing universities.
2: Re-designing the auditorium space by studying noise sources, treating them,
And studying reverberation time to make it suitable for learning spaces.

7-1 Case Study in Egypt: Modern Academy for Engineering:

Current Station Internal: Lecture Hall

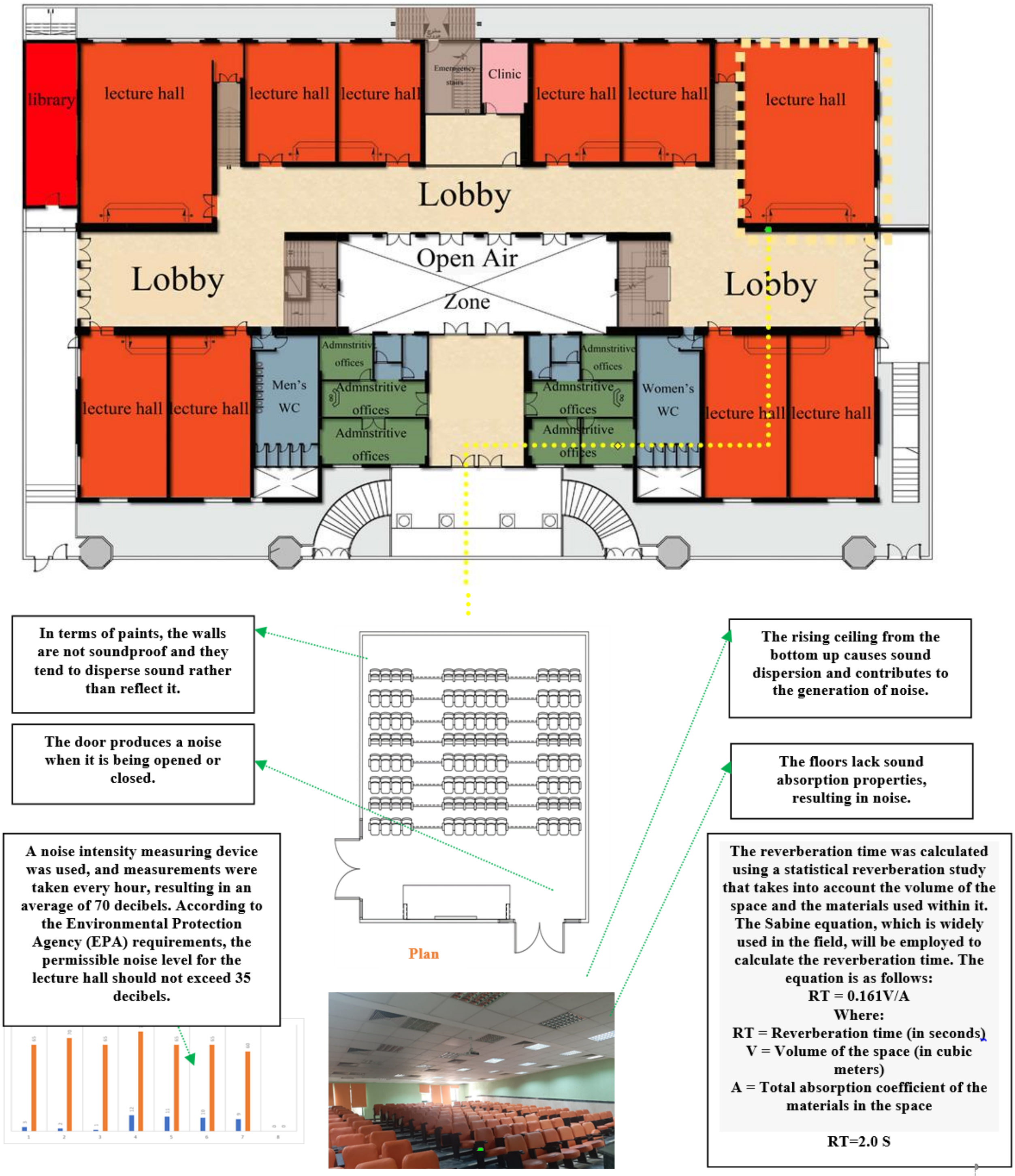


Fig. 14 Current Station (source: researcher)

Acoustics process: The alternative (1)

The primary objective of Alternative (1) is to decrease the response time (RT) from 2 seconds to 1.4 seconds through the implementation of redesign techniques and the substitution of current materials with acoustic materials treatment.

1-walls	2-Ceilings	3-Floors
For sound insulation in walls, a common approach involves the construction of double walls with an intervening space filled with rock wool. Rock wool is a widely used material known for its sound-absorbing properties. By incorporating these double walls and filling the gap between them with rock wool, effective sound insulation can be achieved.	High-density mineral fiber is compressed and shaped into tiles using a high-pressure binder. These tiles are intentionally designed to be porous, featuring small holes or fissures that greatly enhance their acoustical and sound-absorbing capabilities.	Rubber cork acoustic foam sound insulation pads, also known as sound deadening underlay, are specifically designed to provide impact absorption and soundproofing properties for floor applications. These pads consist of a combination of rubber and cork materials, which contribute to their sound insulation characteristics. The foam composition helps to mitigate sound transmission and minimize impact noise, creating a quieter and more acoustically comfortable environment.
4- Air conditioner	**5- WINDOWS**	**6-DOORS**
Sound insulation foam is used to insulate the air conditioner.	Soundproof curtains, crafted from dense and heavy-weight fabrics, are specifically designed to minimize sound leakage through glass windows. These curtains effectively reduce sound transmission, preventing noise from escaping outside or entering the external environment. The dense nature of the fabric and its weight contribute to sound absorption, providing an additional layer of sound insulation to enhance the overall acoustic performance of the space.	A door sweep, also referred to as a draft blocker, is a device that is installed at the bottom of a door to fill the gap between the door and the floor. Its primary purpose is to prevent drafts from entering the room, but it also serves as an effective measure for blocking sound transmission. By sealing off the gap, the door sweep helps to minimize the passage of sound waves, thereby reducing the amount of noise that can enter or exit through the door.

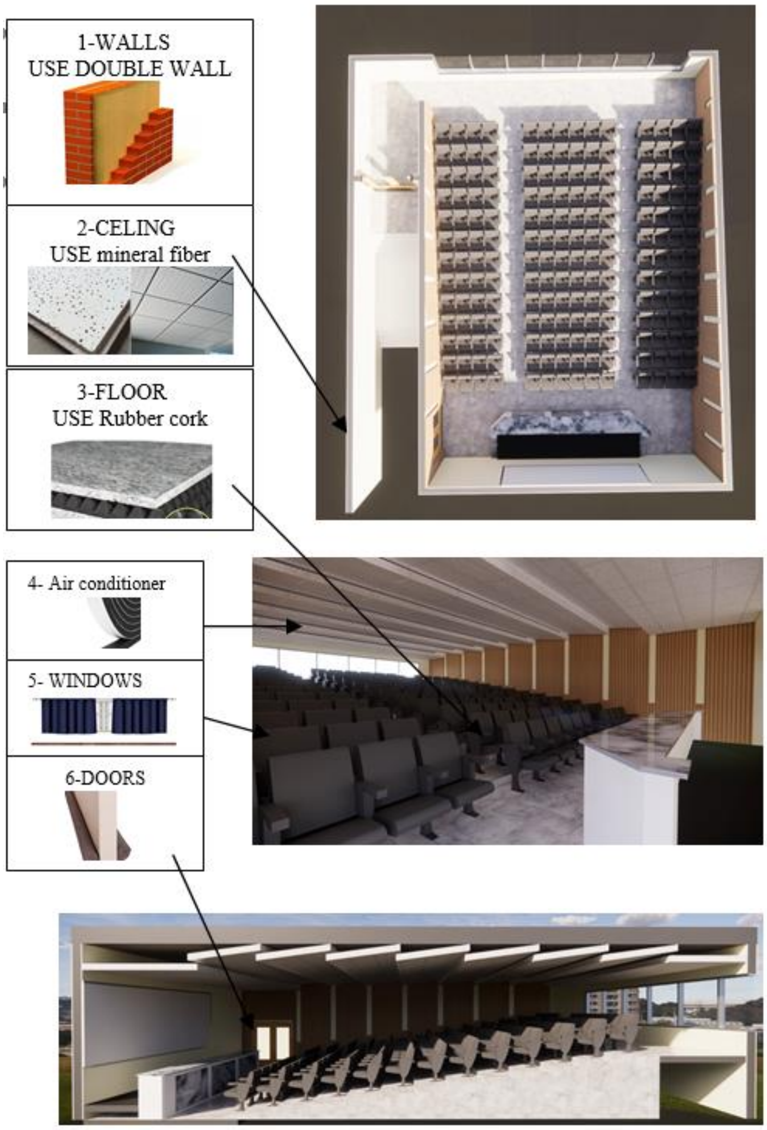


Fig. 15 Acoustics process in lecture hall (source: researcher)

current station : External

The building is located in a residential area, surrounded in all directions by its residential buildings. This contributes to the noise reaching the building block.

Before

There's no landscape for the building, it's not surrounded by trees, so the noise reaches the building without any hindrance.

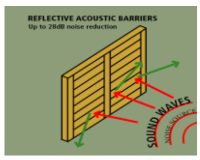
The utilization of non-insulated glass in the building's facade can contribute to increased noise levels within the interior spaces.

The exterior wall thickness of the building is 12 cm brick, so the noise reaches the building without any hindrance.

Before A noise intensity measuring device was used, and measurements were taken every hour, resulting in an average of 70 decibels.

After

The **process** have contributed to reducing noise levels from 70 decibels to 35

PROCESSING TYPE	SOLUTION	
1- tree fence	When making a tree fence for sound isolation and noise reduction from surrounding streets, the following measures can be taken: the thicker the wall, the greater the sound insulation it provides.	
2- The surrounding fence	Constructing a stone wall with a substantial thickness: Using a thick stone wall helps in sound insulation by reducing noise transmission. The thicker the wall, the greater the sound insulation it provides.	

3- Windows insulation	Installing double or triple glazed panels: Double or triple glazing involves using multiple layers of glass with air or gas-filled spaces in between. This configuration significantly enhances sound insulation by creating additional barriers for sound waves. Ensuring tight window seals: Properly sealing windows is crucial for preventing sound leakage...	
4- Soundproofing paint	Using soundproofing paints on the external face to reduce noise, like ISO NEM anti-sound paint (Iconic)	
5-Sound insulation breakers	Installing window breakers wooden breakers, can be placed around the windows to enhance sound insulation. These breakers act as additional layers of insulation, reducing the direct transmission of sound through the windows. They help to block and absorb sound waves, minimizing noise from the surrounding area.	

Fig. 16 Acoustics process In External (source: researcher)

❑ Acoustics process with AI The alternative

"The alternative (2) aims to reduce the response RT From 2 s to 0.8 s by using keywords on the Prome AI application to find a design alternative and replace the current materials with others that help improve the sound."

1-walls	2-Ceilings	3-Floors
Micro Metal Acoustic Panels (MMAPs) represent cutting-edge technology in the field of architectural acoustics. These panels, specifically designed for application on walls and ceilings, are constructed using micro-perforated aluminum. The primary objective of MMAPs is to effectively attenuate echo and sound reflections within a given space. The utilization of micro-perforated aluminum in the manufacturing process of MMAPs enables them to possess exceptional sound-absorbing properties. The intricate perforations in the aluminum surface facilitate the absorption of sound waves, thereby minimizing the occurrence of undesirable acoustic phenomena such as echo and sound reflections. By absorbing and dissipating sound energy, MMAPs create an acoustically optimized environment that is conducive to clear and intelligible communication.		Acoustic floor tiles are purposefully manufactured to effectively mitigate the occurrence of echo and reverberation within spaces that feature hard surfaces and flooring.

4- Air conditioner	5- WINDOWS	6-DOORS
Sound insulation foam is used to insulate the air conditioner.	Double glazed windows possess the remarkable capability of attenuating sound levels by up to 31 decibels.	A door sweep, also referred to as a draft blocker, is a device that is installed at the bottom of a door to fill the gap between the door and the floor. Its primary purpose is to prevent drafts from entering the room, but it also serves as an effective measure for blocking sound transmission. By sealing off the gap, the door sweep helps to minimize the passage of sound waves, thereby reducing the amount of noise that can enter or exit through the door.

USE DISECRAPTION
acoustics processing, reduction noise process, acoustics materials, noise control area, acoustics treatment faced, reduce reverberation time form 2 second to 0.8 second

Fig. 17 Acoustics process in lecture hall (source: researcher)

8. Result of Acoustics process:

Has resulted in reverberation times RT ranging from 2 to 1.4, according to the Sabine equation in alternative (1). This is a suitable time frame for providing an acoustically comfortable environment for lectures but is arrive more effective RT=0.8 s Work on this challenge alternative (2) by help AI application and Sabine equation RT ranging from 2s to 0.8s. Additionally, the **process** has contributed to reducing noise levels from 70 decibels to 35. According to Environmental Protection Agency (EPA) requirements, the permissible noise level for the lecture hall should not exceed 35 decibels.

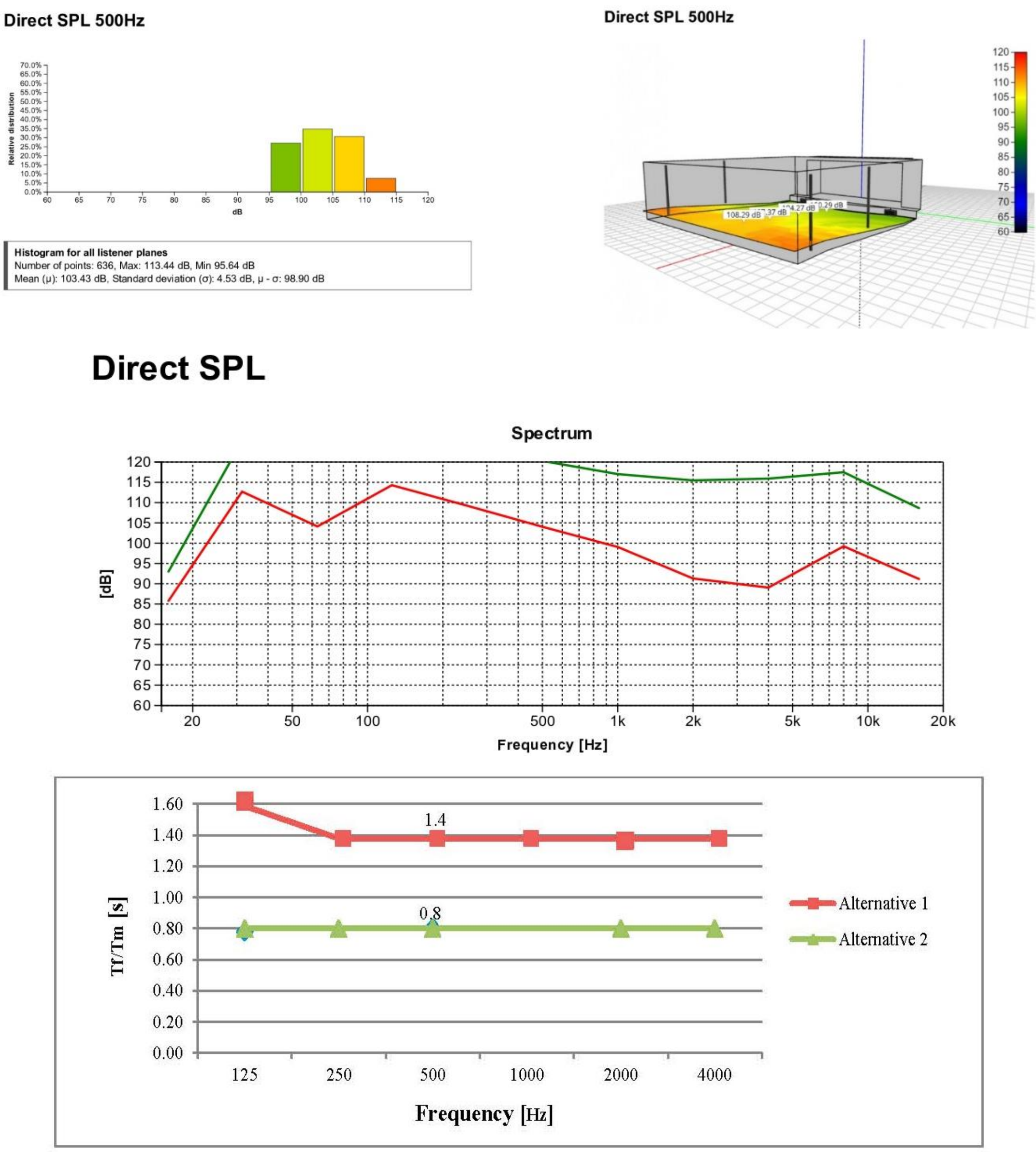


Fig. 18 The use of simulation software to measure sound levels before and after processing. (source: researcher)

9. Conclusion

The utilization of sound process during the design phase or renovation of university buildings can yield various outcomes and significantly influence their academic efficiency. Some of these notable outcomes encompass the following:

1. Enhanced auditory reception and comprehension: The integration of sound processors facilitates the mitigation of disturbances and reverberation, thereby augmenting sound quality and optimizing individuals' capacity to actively engage with and comprehend academic lectures and scientific presentations.
2. Establishment of an acoustically comfortable environment: By effectively mitigating noise levels and minimizing echo, university buildings can foster a serene soundscape conducive to concentration, cognitive focus, and overall well-being for students, faculty members, and staff.
3. Promotion of effective communication: Sound processors play a pivotal role in elevating the quality of auditory communication among individuals within university settings. The provision of clear and intelligible sound fosters optimal opportunities for effective understanding and meaningful interaction between students, faculty members, and the academic community at large.
4. Amplification of academic performance: A favorable sound environment has the potential to exert a positive influence on overall academic performance. By enhancing sound quality and diminishing disruptive noise, students and faculty members can optimize their concentration, productivity, and engagement within the academic milieu.

These outcomes underscore the profound impact that sound processors can have on bolstering the academic efficacy and success of university buildings.

6. References

[1] Munteanu, Constantin, et al. "The acoustic properties of the lecture hall of the Faculty of Building Services in Cluj-Napoca." Procedia Manufacturing 22 (2018): 331-338.

[2] El Samra, G. "Community noise in Greater Cairo." Egyptian Journal of Occupational Medicine 40.2 (2016): 267-285.

[3] Vigran, Tor Erik. Building acoustics. CRC Press, (2014).

[4] https://theconstructor.org/building/noise-control-in-buildings-acoustic/14640/

[5] Ryu, Jong Kwan, and Jin Yong Jeon. "Influence of noise sensitivity on annoyance of indoor and outdoor noises in residential buildings." Applied Acoustics 72.6 (2011): 336-340.

[6] Novakovic, K. "Control of static and dynamic mechanical response of piezoelectric composite shells: applications to acoustics and adaptive optics." Technical university of Liberec, Ph. D. Thesis, Liberec (2013).

[7] Yang, Hong-Seok. Outdoor noise control by natural/sustainable materials in urban areas. Diss. University of Sheffield, 2013.

[٨] Lacasta, A. M., et al. "Acoustic evaluation of modular greenery noise barriers." Urban Forestry & Urban Greening 20 (2016): 172-179.

[٩] Stetsky, Sergey, and Ekaterina Dorozhkina. "Position of residential buildings in the urban tissue in relation to environmental affect: a review." E3S Web of Conferences. Vol. 244. EDP Sciences, 2021.

[10] Busa, Lucia, Simone Secchi, and Stefano Baldini. "Effect of façade shape for the acoustic protection of buildings." Building Acoustics 17.4 (2010): 317-338.
[11] Cavanaugh, William J., et al. "Architectural acoustics: Principles and practice." Noise Control Engineering Journal 58.5 (2010): 557-558.
[12] Vasconcelos, Graça, et al. "Proposal of an innovative solution for partition walls: Mechanical, thermal and acoustic validation." Construction and Building Materials 48 (2013): 961-979.
[13] https://akinco.ae/products/acoustic-partitions/
[14] Yang, Won young, and Jin Yong Jeon. "Design strategies and elements of building envelope for urban acoustic environment." Building and Environment 182 (2020): 107121.
[15] https://commercial-acoustics.com/treating-mechanical-noise/
[16] Tao, Yinping, et al. "Recent progress in acoustic materials and noise control strategies–A review." Applied Materials Today 24 (2021): 101141.
[17] https://www.newscientist.com/article/mg23531350-300-sponsored-towards-the-sound-of-silence/
[18] Asdrubal, Francesco, Francesco D'Alessandro, and Samuele Schiavoni. "A review of unconventional sustainable building insulation materials." Sustainable Materials and Technologies 4 (2015): 1-17
[19] https://www.straehle.de/en/service/interesting-facts/sound-insulation/
[20] Santoni, Andrea, et al. "Improving the sound absorption performance of sustainable thermal insulation materials: Natural hemp fibres." Applied Acoustics 150 (2019): 279-289.
[21] Su, Zühre, and Mehmet caliskan. "Acoustical design and noise control in metro stations: case studies of the Ankara metro system." Building Acoustics 14.3 (2007): 203-221.