



## Journal of Development and Integrated Engineering

Journal homepage:  
<https://ejournal.upi.edu/index.php/jodie>



# Comprehensive Study on Sound Quality and Room Design of FPSD Auditorium UPI

Tahira Chandra<sup>1\*</sup>, Balebat Giwangkara Sutanto<sup>2</sup>, Beta Paramita<sup>3</sup>

<sup>1,2,3</sup> Universitas Pendidikan Indonesia, Bandung, Indonesia

\*Correspondence: E-mail: [tahirachandra16@upi.edu](mailto:tahirachandra16@upi.edu)

### ABSTRACT

*Speech auditorium is an auditorium that has special functions such as for speeches, seminars, lectures conferences and others. thereby impairing the acoustic performance of the auditorium, Good acoustic quality performance in an auditorium is also influenced by subjective and objective factors arising from the internal design of acoustic surfaces (floors, partitions, ceilings) and dimensions influenced by the maximum capacity audience. The research method is divided into three stages. Data collection in the form of field data and literature review, data collection in the form of documentation and observation in the field, and then processing as much data as possible to draw conclusions from the data obtained in the field. The analysis method used in this research is qualitative, The auditorium is designed in various forms to maximize performance and adapt to the activities taking place within. These activities include art performances, music concerts, conferences, and seminars. The choice of auditorium shape is based on visitor capacity, facility integrity, and visual elements. There are various types of auditoriums, depending on their sound systems. In conclusion, the research underscores the importance of creating an ideal auditorium space tailored for speeches. The meticulous application of acoustic principles, including optimal reverberation time, initial time delay gap, and strategic placement of sound-absorbing materials, is crucial in achieving an acoustically superior environment.*

### ARTICLE INFO

#### Article History:

Submitted/Received 1 March 2025

First Revised 14 July 2025

Accepted 10 October 2025

First Available 1 December 2025

Publication 1 December 2025

#### Keywords:

Auditorium,  
Acoustic,  
Ecotect,  
Sound-Absorption Material

## 1. INTRODUCTION

The auditorium is a large room that can be used for various purposes, including: meetings, performances, etc. (li et al., 2008). Speech auditorium is an auditorium that has special functions such as for speeches, seminars, lectures conferences and others (Hedy C. Indrani et al., 2007b).

Most auditoriums have problems with background noise levels that exceed the required noise standards, thereby impairing the acoustic performance of the auditorium, Good acoustic quality performance in an auditorium is also influenced by subjective and objective factors arising from the internal design of acoustic surfaces (floors, partitions, ceilings) and dimensions influenced by the maximum capacity of the audience. In addition, the use and application of absorbent or reflective coating materials are considered on all sides (Hedy C. Indrani et al., 2007a).

Acoustics are an important part of the Auditorium design features. All learning activities require high quality sound. Poor auditorium acoustic design affects the concentration of students and teachers. To ensure good listening conditions, acoustic requirements must be taken into account during the design stage. In addition to considering the acoustic requirements of the auditorium space, external noise factors also cause disruption to lectures in the auditorium (Arinta et al., 2022).

The comfort of the teaching and learning process can be influenced by various factors such as lighting, ventilation, and acoustic quality. The design of the auditorium space in the Education Building requires a fairly high level of quietness.

Reverberation time is the time in seconds required for sound to weaken by 60 dB. Rooms where audio must be heard clearly such as classrooms, auditoriums, and auditoriums require a reverberation time of 0.6 seconds to 0.8 seconds (Mediastika, 2005).

Reverberation time is important for measuring speech clarity. Direct speech is greatly affected by sound reflections in a room with a long reverberation time, resulting in inadequate speech understanding. On the other hand, whereas auditorium with too short reverberation time will give the impression that the room is "dead" (Hedy C. Indrani et al., 2007a).

Table 1. Reflection Quality Table

| Difference in Sound Travel Distance Between the Summation of Reflected Sound and Direct Sound | Time Delay Gap | Reflection Quality |
|-----------------------------------------------------------------------------------------------|----------------|--------------------|
| <7                                                                                            | <20            | Perfcct            |
| 7-10                                                                                          | 20-30          | Good               |
| 10-15                                                                                         | 30-45          | Normal             |
| 15-20                                                                                         | 45-60          | Poor               |
| >20                                                                                           | >60            | Echo appears       |

Source: Kualitas Pemantulan Akibat Selisih Jarak Antara Penjumlahan Bunyi Langsung dan Bunyi Pantul, Satwiko (2004)

This sound reflection problem can be overcome by the use of materials that can absorb or reflect sound and also the application of forms that can reduce sound resonance so that the auditorium can be used optimally both for lectures, seminars, or other learning activities.

## 2. METHODOLOGY

The research method is divided into three stages. Data collection in the form of field data and literature review, data collection in the form of documentation and observation in the field, and then processing as much data as possible to draw conclusions from the data obtained in the field. The analysis method used in this research is qualitative, and the research variables consist of the shape and proportion of studio space, acoustic materials, and ceiling

design.

Prior to conducting observations, the researcher first gathers data related to the auditorium space. This includes information on the materials commonly used in auditoriums, the height from the floor to the ceiling, and the acoustic standards that must be met by the auditorium space. The researcher managed to get the floor plan of the FPSD auditorium.

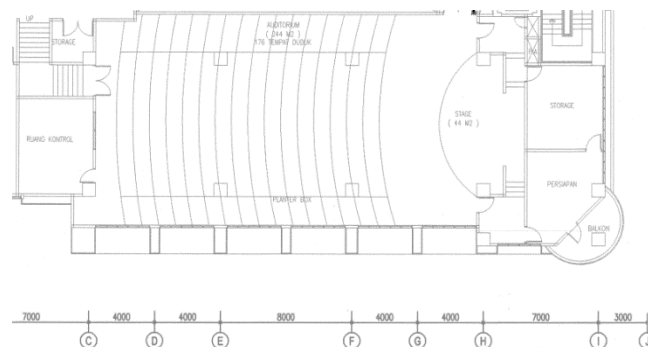


Figure 1. Floorplan Auditorium FPSD

Observations are then conducted on-site, assessing the implementation of materials and aligning them with the data collected during the data collection phase.

Furthermore, researchers used ecotect software to process the data that had been determined. As a computer-aided building performance simulation program, Ecotect offers the opportunity to approach acoustic design as well as analyze lighting, thermal and cost. The graphical user interface runs on the Windows platform, making the program easy to use for designers. Especially for acoustic analysis, Ecotect is not only based on the calculation of reverberation time analysis based on the Sabine, Eyring and Millington reverberation statistical formulas, but also the analysis of acoustic geometry (acoustic particles) which can be visualized (Latifah et al., 2023)(Santoso Mintorogo et al., 2007).

Initially, a comparable modeling process was undertaken for the FPSD auditorium using the Ecotect software, referencing the obtained floor plan. Subsequently, adjustments pertaining to the materials used in the auditorium were made. The following are some materials implemented in the Ecotect software. Subsequently, simulations were conducted using Ecotect software, such as statistical or particle acoustic simulation methods.

The results of these simulations allow for the attainment of areas that meet high-quality standards. Additionally, in the Ecotect software, suitable material options for the auditorium are identified, along with the recommended forms to optimize the audio quality. Researcher identifies the points or areas of the sound source, considering that the auditorium serves both as a lecture hall and a venue for speeches, with features like a raised podium from the ground floor. This is where the researcher designates the point or source of sound for simulation.

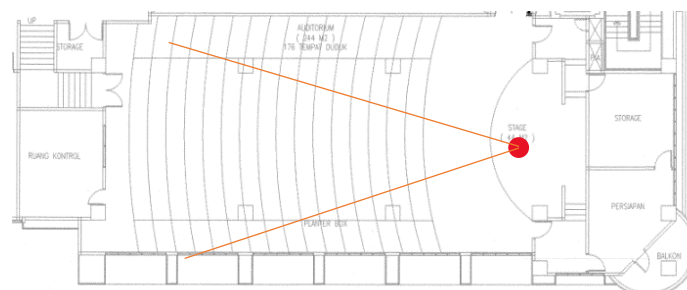


Figure 2. Measuring Point Position

The chosen position is considered highly ideal and frequently utilized as the sound source during speeches or lectures. Hence, the researcher selects this point as the focal point for simulating the sound source.

### 3. RESULTS AND DISCUSSION

#### 3.1. Proportion of Studio Space

The auditorium is designed in various forms to maximize performance and adapt to the activities taking place within. These activities include art performances, music concerts, conferences, and seminars. The choice of auditorium shape is based on visitor capacity, facility integrity, and visual elements. There are various types of auditoriums, depending on their sound systems. The auditorium shape can vary based on the requirements of these sound systems (Doelle, 1993).

One classification is the square-shaped auditorium, which is the simplest form of auditorium space. This shape is employed in the FPSD auditorium. The stage is positioned on one side, while the audience area is located on the other side. This configuration has a drawback as audience members on the sides may face difficulty in enjoying the performance, potentially reducing the comfort level for those spectators. The square-shaped auditorium form is also utilized in the BCH Auditorium (li et al., 2008).

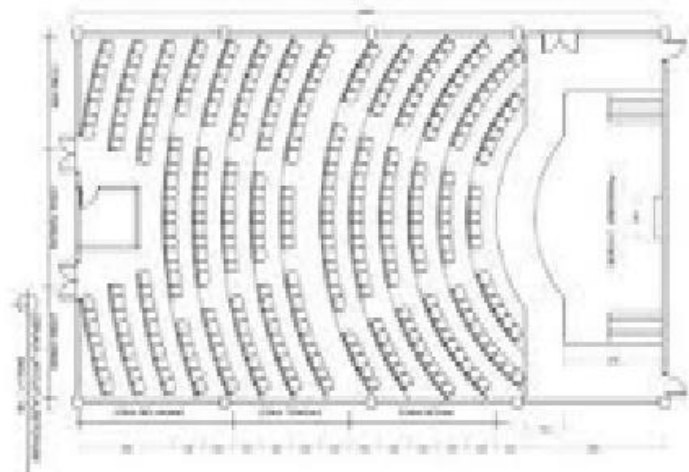


Figure 3. Example of a rectangular auditorium.

Source: <https://temuilmiah.iplbi.or.id/>

The rectangular room shape is chosen due to its high sound uniformity, ensuring a well-balanced distribution between the first and last tones. The narrow width allows for effective response to lateral or transverse noise, enhanced by repeated reflections between the side walls. This configuration results in improved performance, meeting the desired acoustic aspects in an auditorium space. (Pemilihan et al., n.d.)

#### 3.2. Accoustic Materials

The observation results reveal that the materials used in the construction of the FPSD auditorium have a remarkably high level of audio absorption. The walls incorporate wood wool panel material designed for sound absorption. The acoustic properties of the wood wool panels were tested, including sound absorption coefficient ( $\alpha$ ) and transmission loss (TL). The sound absorption coefficient ( $\alpha$ ) was measured in accordance with JIS A 1405 (1963) using an impedance tube, with the test specimen shaped in a circular form with a diameter of 9.8 cm and a frequency of 100 Hz. For frequencies between 1600 Hz and 4000 Hz, the test samples had a diameter of 4.8 cm (Beberapa et al., 2011).



Figure 4 & 5. Materials Used (Wood wool panels)  
Source: Personal Documentation

The sound absorption coefficient ( $\alpha$ ) at 250 Hz on wood wool panels varies, with peak sound absorption occurring at frequencies of 125 Hz and 200 Hz, with an approximate  $\alpha$  value of 0.7. Additionally, at a frequency of 250 Hz, the sound absorption value decreases to around 0.1.

At low frequencies, wood wool panels with a density of 0.8 g/cm<sup>3</sup> provide higher  $\alpha$  values compared to dense wood wool panels (1.0 g/cm<sup>3</sup>) for all wood types. In the medium frequency range between 300 and 800 Hz, the sound absorption coefficient of wood wool panels ranges between 0.1 and 0.4. For synthetic isocyanate-based adhesive wood wool panels, the  $\alpha$  value in the medium frequency range tends to increase with higher frequencies. The following are the data from the research results:

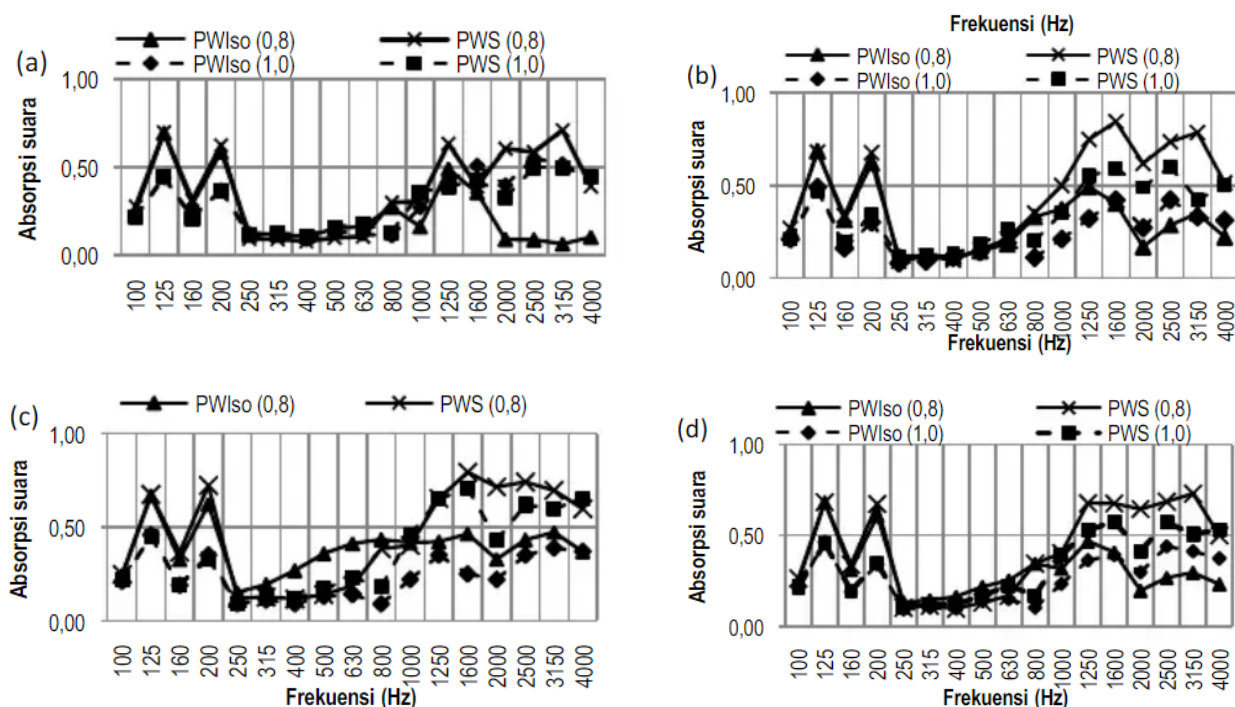


Figure 6. Sound absorption coefficient graph of wool board (PW) density 0.8 and 1.0 g/cm<sup>3</sup> (a. PW sengan; b. PW African wood; c. PW mangium; PW all wood species).

Source: Ecotect

### 3.3. Ceilling Design

In addition to the walls utilizing wood wool as both a covering and sound absorber, the ceiling also employs a similar material for enhanced sound absorption. However, there is one distinct area where the roof features a regular wave-like pattern. This design is intended

to prevent sound reflections from bouncing back upwards towards the ceiling or seating area, thus avoiding the occurrence of flutter echo (li & Pustaka, 2002).

The shape and pattern of the ceiling play a significant role in the acoustics of the auditorium, enriching useful early reflections. This is because the ceiling is a reflective surface with a broader coverage area compared to reflections originating from the side walls, which are limited to their immediate surroundings. Therefore, the ceiling pattern must be designed in such a way that sound reflections are directed accurately. Lighting and ventilation system fixtures installed on the ceiling panels will adjust when the volume settings on the panels are lowered or raised (Juwita, 2017).

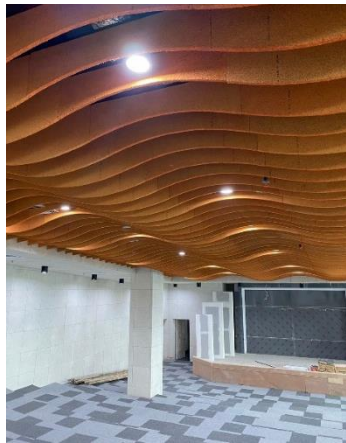


Figure 7. Ceiling Design at Auditorium FPSD UPI

Source: Personal Documentation

Indeed, the wavy pattern on the ceiling in the FPSD Auditorium serves the purpose of minimizing reflections. This design choice, along with using the same material as the walls, ensures consistency and optimal sound absorption throughout the space. This setup is particularly effective when the room is used for speeches or lectures, creating a quiet atmosphere where the sound from the source is clear and distinct. The absorption properties of the materials used, combined with the applied patterns, contribute to an environment where extraneous noises are absorbed, enhancing the overall acoustic experience.

### 3.4. Ecotect Simulation

Subsequently, the data is processed using Ecotect software. To fulfill the need for analyzing the influence of the absorption field position on reverberation time, a specialized combination model was constructed, taking into account sound propagation. This model is referred to as the "design" model. The Link Acoustic Lines feature can be utilized to trace sound propagation within a room and identify which areas of the room are designed as reflective or absorptive zones (Istiadji & Binarti, 2007).

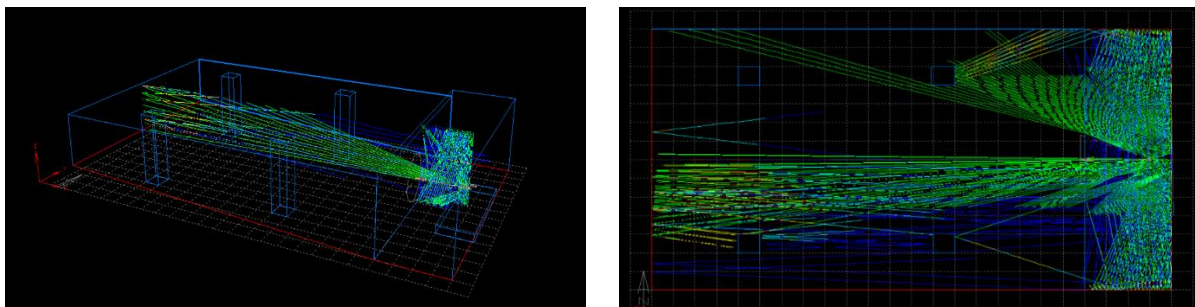


Figure 8 & 9. Vertical and Horizontal Cut of Sound Reflection from Simulation Results with Sound Travel Approach

Source: Ecotect Simulation

Based on the above diagram, the reflection results from the sound source are quite optimal and reach sufficiently large areas. Sound waves moving horizontally towards the front will be reflected at acute angles and can be repeatedly reflected on the opposite wall. To address this, sound-absorbing materials are used on the left side and right side.

Now, observe the sound lines hitting the back wall (BLK) as indicated. The reflected sound propagation time (4B) ranges from 35 ms to 48 ms. This value is close to the desired propagation time limit. To dampen the reflected sound energy (while reducing propagation time), the BLK wall is constructed with sound-absorbing material. Take note of the vertical sound lines indicated in the diagram.

As the ceiling of this space incorporates areas with wave patterns, sound reflections are not too pronounced. However, sound wave reflections still occur directly above the source, raising concerns about potential flutter echo. The design solution can involve either applying the aforementioned wave pattern or creating a new convex pattern to prevent repeated sound reflections, thus mitigating the risk of flutter echo.

The next piece of information pertains to the reverberation time of this room, and this data can demonstrate that the auditorium's reverberation time is appropriate for functioning as both a speech room and a lecture hall. The reverberation time for these purposes should ideally be very minimal.

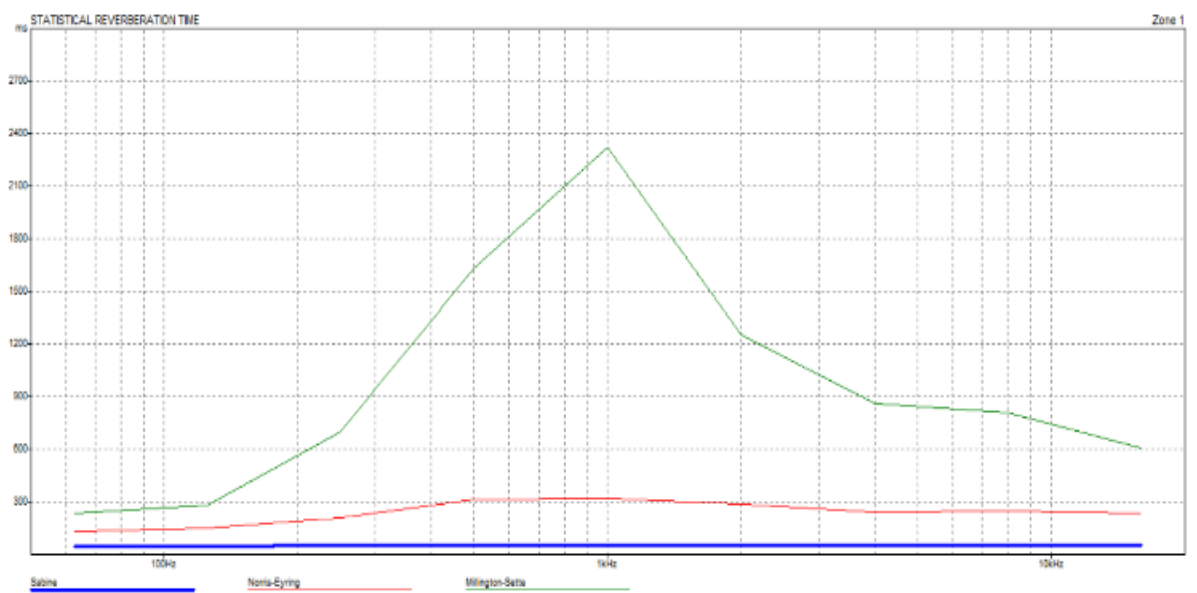


Figure 10. Existing Condition Buzzing Time Chart  
Source: Ecotect Simulation

Table 2. Reverbation Time Analysis Results Table

| FREQ.  | TOTAL ABSPT. | SABINE RT(60) | NON-ER RT(60) | MIL-SE RT(60) |
|--------|--------------|---------------|---------------|---------------|
| 63Hz:  | 901.720      | 0.05          | 0.13          | 0.23          |
| 125Hz: | 877.031      | 0.05          | 0.16          | 0.29          |
| 250Hz: | 804.843      | 0.05          | 0.21          | 0.70          |
| 500Hz: | 772.384      | 0.06          | 0.32          | 1.63          |
| 1kHz:  | 764.800      | 0.06          | 0.32          | 2.33          |
| 2kHz:  | 779.620      | 0.06          | 0.29          | 1.25          |
| 4kHz:  | 793.601      | 0.05          | 0.25          | 0.87          |
| 8kHz:  | 795.188      | 0.05          | 0.25          | 0.81          |
| 16kHz: | 810.729      | 0.05          | 0.24          | 0.61          |

Source: Ecotect Simulation

For speech auditoriums, the recommended reverberation time (RT) is within the range of 0-1 second, with an optimum RT of 0.75 seconds. Meanwhile, for music auditoriums, it is advisable to have a reverberation time within the range of 1-2 seconds, with an optimum RT of 1.5 seconds (Kasus et al., 2014). The table and the above diagram illustrate the reverberation time analysis results obtained from the FPSD Auditorium simulation using Ecotect software. Based on the table results, at a frequency of 500 Hz, the total absorption or absorption reached 772.384, which is quite favorable for use as a venue for speeches and lectures. This is attributed to the use of sound-absorbing materials and the implementation of wave patterns on the ceiling to dampen sound (Febrianto et al., 2016).

The calculation of RT in Ecotect is based on three equations: Sabine, Norris-Eyring, and Millington-Sette (Table III). The Norris-Eyring equation is more suitable for average absorption coefficients of rooms greater than 0.1 or those that absorb sound well, such as recording studios. The results of the Ecotect RT calculation are displayed for frequencies ranging from 63 Hz to 16000 Hz (Yani, 2021).

Acoustic models involve complex modeling of various elements within the auditorium, including walls, ceilings, and other acoustic materials. To observe the distribution of sound energy, termed as homogeneity, generated by the existing acoustic particles method (Istiadji & Binarti, 2007).

With an evenly distributed sound energy, the functionality of the room can be optimized. Delay time should also be considered in the construction of the auditorium, especially if the auditorium is intended for educational purposes rather than musical events or situations that require a higher delay time. The delay time should be minimized as much as possible. Subsequently, data related to the distribution of sound energy was obtained as follows.

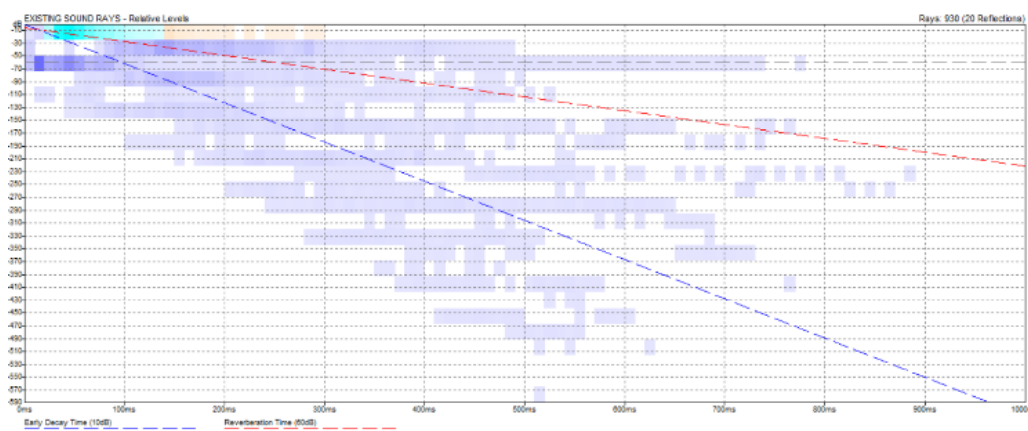


Figure 10. Delay Time Grafik

Source: Ecotect Simulation

The initial time delay gap, which refers to the interval or delay in the appearance of the first sound reflection after the original sound, plays a crucial role in establishing intimacy between the space and the audience within it. For musical environments, a desirable initial time delay gap falls within the range of 12-25 milliseconds. This factor is of paramount importance in determining the choice of acoustic materials and their respective configurations.

It is crucial to strike the right balance between reducing time delay and meeting the specific acoustic environment requirements desired. Each step taken must be meticulous, considering the unique characteristics of the space and the intended acoustic functionality. Alongside this consideration, various strategies can be applied to achieve optimal results.

In the case of the provided data, where the delay is still considered relatively high for speech purposes, it is acknowledged that the wave pattern on the ceiling in the middle of the audience seating area has contributed to addressing this issue. Interestingly, the addition of a wave pattern on the back wall of the room could be an effective supplementary solution. This aligns with acoustic theory stating that the use of wave patterns on specific surfaces can optimize the spread and absorption of sound in a room. Of course, the implementation of these strategies needs to be tailored to the unique characteristics of the space and the specific requirements for speech. A holistic and comprehensive acoustic analysis will ensure that the actions taken can bring about significant improvements without compromising the overall acoustic quality.

#### **4. CONCLUSIONS**

In conclusion, the research underscores the importance of creating an ideal auditorium space tailored for speeches. The meticulous application of acoustic principles, including optimal reverberation time, initial time delay gap, and strategic placement of sound-absorbing materials, is crucial in achieving an acoustically superior environment. The utilization of wave patterns on surfaces, such as ceilings and walls, has proven to be effective in minimizing time delay and enhancing sound distribution. It is evident that a careful balance must be struck between reducing time delay and meeting the specific acoustic requirements for speech purposes. This study contributes valuable insights for designing and implementing auditoriums that not only adhere to established standards but also create an optimal acoustic setting for impactful and clear speech delivery.

FPSD auditorium is deemed highly commendable, given its incorporation of sound-absorbing materials like wood wool and the implementation of wave patterns on its ceiling. This makes it exceptionally comfortable for various purposes, including speeches, lectures, and seminars. The auditorium serves as a noteworthy benchmark for the design of other auditoriums, specifically tailored for speech-related functions. The distinct application of various aspects distinguishes it from auditoriums designed for musical performances, emphasizing its specialization in providing an optimal acoustic environment for speech-related activities.

The utilization of Ecotect allows for precise modeling, analysis, and optimization of various acoustic elements, including the placement of sound-absorbing materials, strategic design of ceilings and walls, and the overall configuration of the auditorium. By adhering to established standards and leveraging advanced software tools, the study provides valuable insights into creating an acoustically superior environment for impactful and clear speech delivery in auditoriums.

#### **Acknowledgments**

With deep gratitude, we would like to express our thanks to the Almighty for the blessings, guidance, and opportunities provided throughout the course of this research. Not forgetting, we extend our heartfelt appreciation to our mentors, Dr. Eng. Beta Paramita, ST., and Mr. Try Ramadhan, for their invaluable guidance, encouragement, and knowledge shared during the research process. They have been a source of inspiration and immeasurable support. Also, our sincere thanks go to all parties involved in supporting and contributing to this research. Every contribution, whether direct or indirect, has played a crucial role in the success of this project. May the outcomes of this research bring benefits and positive contributions to the advancement of knowledge and its practical applications. Our thanks are conveyed genuinely and humbly.

## Reference

- Arinta, R. T., Delima, T., Sp, S., Ashary, E., & Sulistiyoningsih, A. (2022). Acoustic Performance of Al-Muhajirin Mosque semarang. *International Journal of Innovative Science and Research Technology*, 7(6), 1309–1313. [www.ijisrt.com](http://www.ijisrt.com)1309
- Beberapa, D., Cepat, K., Karlinasari, L., Dari, B. S., Kayu, B., Tumbuh, C., Karlinasari, L., Hermawan, D., Maddu, A., & Martianto, B. (2011). *SIFAT PENYERAPAN DAN ISOLASI SUARA PAPAN WOL BERKERAPATAN SEDANG-TINGGI Sound Absorption and Sound Insulation Characteristics of Medium-High*. 4(January), 8–13.
- Febrianto, R. S., Ujianto, B. T., Utomo, B. J. W., Sukowiyono, G., & ... (2016). Jurnal karya ilmiah mahasiswa arsitektur. *Lintar.Untar.Ac.Id*, V. [https://lintar.untar.ac.id/repository/penelitian/buktipenelitian\\_10315004\\_5A105359.pdf](https://lintar.untar.ac.id/repository/penelitian/buktipenelitian_10315004_5A105359.pdf)
- Hedy C. Indrani, Sri Nastiti N. Ekasiwi, & Wiratno A. Asmoro. (2007a). ANALISIS KINERJA AKUSTIK PADA RUANG AUDITORIUM MULTIFUNGSI Studi kasus: Auditorium Universitas Kristen Petra, Surabaya. *Dimensi Interior*, 5(1), 1–11. <http://puslit2.petra.ac.id/ejournal/index.php/int/article/view/16870>
- Hedy C. Indrani, Sri Nastiti N. Ekasiwi, & Wiratno A. Asmoro. (2007b). OPTIMASI DESAIN INTERIOR UNTUK PENINGKATAN KUALITAS AKUSTIK RUANG AUDITORIUM MULTI-FUNGSI (Studi kasus Auditorium Universitas Kristen Petra, Surabaya). *DIMENSI (Jurnal Teknik Arsitektur)*, 35(2), 117–127. <http://puslit2.petra.ac.id/ejournal/index.php/ars/article/view/16742>
- li, B. A. B., & Pustaka, T. (2002). *BAB II Tinjauan Pustaka BAB II TINJAUAN PUSTAKA 2.1*. 1–64.
- li, B. A. B., Teori, T., & Kebijakan, D. A. N. (2008). *Bab ii tinjauan teori dan kebijakan*. 131, 20–52.
- Istiadji, A. D., & Binarti, F. (2007). Studi Simulasi Ecotect Sebagai Pendekatan Redesain Akustik Auditorium. *DIMENSI (Jurnal Teknik Arsitektur)*, 35(2), 107–116. <http://puslit2.petra.ac.id/ejournal/index.php/ars/article/view/16741>
- Juwita, K. (2017). Desain Plafon pada Auditorium Gedung Kesenian Jakarta. *Jurnal Desain Interior*, 2(2), 87. <https://doi.org/10.12962/j12345678.v2i2.3545>
- Kasus, S., Auditorium, R., Gedung, M., & Dan, P. (2014). *KAJIAN PENERAPAN PRINSIP-PRINSIP AKUSTIK UNIVERSITAS KRISTEN PETRA*. 1(1), 14–20. <https://doi.org/10.9744/duts.1.1.14-20>
- Latifah, F. N., Putri, R. S., Syukur, F., Sutarno, W. H., Paramita, B., & Ramadhan, T. (2023). *An Analysis of Prayer Room Acoustics in the Pusdai Mosque in West Java*. 4. <https://doi.org/10.3390/iocbd2023-15187>
- Mediastika, C. E. (2005). Akustika Bangunan. *Erlangga*, 150.
- Pemilihan, A., Ruang, B., Di, P., & Pertunjukan, G. (n.d.). *Analisa pemilihan bentuk ruang penonton di gedung pertunjukan musik*. 341–350.
- Santoso Minto, D., Editor Aditjipto, A. M., Susilo, N., Arifin, L. S., Loekito Kartono, J., Damayanti, R., Spencer Reynolds, J., Kossak, F., Soebarto, V. I., Hamdan Bin Ahmad, M., Widodo, J., Arif Kamal, M., Satwiko, P., Hedy Indrani, P. C., Nastiti Ekasiwi, S. N., & Asmoro, W. A. (2007). *DIMENSI-Journal of Architecture and Built Environment Editor in Chief*. 35(2). <http://dimensi.petra.ac.id/index.php/ars/issue/view/2869>
- Yani, Y. (2021). *Penilaian kualitas akustik masjid raudhaturrahmah Padang Tiji dengan menggunakan simulasi ecotect*. 4(1), 18–26.