

# Interior Redesign with Acoustic Treatment at Gereja “Kristus Tuhan Anugerah” in Surabaya

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## Abstract

The Gereja “Kristus Tuhan Anugerah” in Surabaya faced several interior and acoustic challenges, including insufficient reverberation time and sound leakage into the surrounding residential area. To address these issues, the church underwent an interior redesign that incorporated acoustic simulations using I-Simpa software to develop effective solutions. Key improvements included the installation of absorbent materials to control reverberation time, the application of Sapphire insulation to prevent sound from leaking outside the church, and the installation of Beryl insulation in the Sunday school room to minimize external noise disturbances. As a result of these changes, the interior acoustic quality improved significantly, achieving optimal reverberation time for the worship space while also reducing the noise impact on the neighboring residential area. This project successfully created a comfortable worship environment, enhancing both the interior design and acoustics without disturbing the tranquility of the neighborhood.

**Keywords:** redesign, Protestant church, interior acoustics, I-Simpa software.

## Abstrak

Gereja “Kristus Tuhan Anugerah” di Surabaya menghadapi beberapa masalah interior dan akustik, termasuk waktu dengung yang tidak memadai dan kebocoran suara ke area perumahan di sekitarnya. Untuk mengatasi masalah ini, gereja menjalani redesain interior dengan menggabungkan simulasi akustik menggunakan perangkat lunak I-Simpa untuk menciptakan solusi akustik yang efektif. Perbaikan tersebut meliputi pemasangan material absorber untuk mengendalikan waktu dengung, penerapan insulasi Sapphire untuk mencegah suara musik bocor keluar gereja, dan pemasangan insulasi Beryl di ruang sekolah Minggu untuk meminimalkan gangguan kebisingan eksternal. Sebagai hasil dari perubahan ini, terdapat peningkatan yang signifikan dalam kualitas akustik interior yakni mencapai waktu dengung optimal untuk ruang ibadah sekaligus juga mengurangi dampak kebisingan pada area perumahan di sekitarnya. Studi ini telah berhasil menciptakan ruang ibadah yang nyaman, baik dari segi desain interior dan akustik, tanpa mengganggu ketenangan lingkungan sekitar.

**Kata kunci:** redesain, gereja protestan, akustik interior, software I-Simpa.

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## Introduction

Indonesia is a nation known for its rich ethnic, cultural, racial, and religious diversity, which is especially evident in the various places of worship used by its different religious communities. Religious facilities serve as venues for conducting religious practices (Kusmanto et al., 2023). A church is a structure or space where Christians gather to worship Jesus Christ. Common activities held in churches include public worship, youth services, Sunday school sessions, ministry training, meetings for church workers, counseling, and various congregational activities aimed at strengthening relationships among members and enhancing their spiritual growth (Welhelmina, 2020).

Over time, challenges have arisen in church design, particularly regarding acoustics, which can negatively affect the worship experience. Issues such as excessive reverberation and uneven sound distribution hinder the congregation's ability to hear sermons, prayers, or music clearly. According to Beranek (2004), managing reverberation time and sound distribution is essential for achieving optimal acoustic quality in a worship space. Without adequate acoustic treatment, the comfort and focus of the congregation may be compromised.

The church is located at Babatan Pantai Utara V/6 in Surabaya. Established in 2004, it has faced several interior and acoustical challenges during data collection efforts. It was found that the church needed insulation to address sound leakage, which could disturb neighboring residents by allowing noise to enter their yards. Additionally, in the Sunday school classroom area, noise from passing vehicles often penetrates the rooms, sometimes disrupting the concentration of teachers. These issues can compromise the peace of both the residents and the congregation during worship.

Research into the reverberation times in various areas of the church—specifically the main worship space, the multipurpose area (which hosts Sunday school services and prayer meetings), the Sunday school classrooms, and the youth area—revealed that none of these spaces met the required reverberation time standards. As a result, the authors aimed to optimize the reverberation time. Calculations and optimizations were performed using the I-Simpa v.1.3.4 application. The findings indicated a need for additional acoustic materials to act as sound absorbers. Acoustic insulation was employed to improve sound insulation within the church.

While numerous prior studies have explored solutions to acoustic challenges, there is a notable lack of acoustics journals that focus on optimizing reverberation time to enhance congregational comfort using I-Simpa software. Therefore, the objective of this research is to implement a robust acoustic system through appropriate solutions, ensuring that sermons and praise can be heard clearly and uniformly without disturbing the surrounding environment. It is anticipated that this research will contribute to the advancement of the field of acoustics and raise public awareness of its significance.

This design method was carried out in six stages of design thinking (Razzouk & Shute, 2012). The process began with a literature review and direct field observations to gather insights into design standards, user activity patterns, and acoustic challenges. This involved conducting interviews, distributing questionnaires, and taking field measurements. The information collected was then analyzed using techniques like behavior mapping, bubble diagrams, and affinity diagrams to determine optimal space requirements and circulation patterns. The concept and design were further refined through exploratory sketches, study mockups, and storyboarding, ultimately resulting in an interior design that prioritizes acoustic comfort for users. In the final stage, 3D prototypes, technical documentation, and physical mockups were created to assess the acoustics. The design results were presented to the church council through a video walkthrough to gather their feedback.

The findings of the study indicated a significant improvement in both interior and acoustic quality, achieving a reverberation time that met established standards and thereby reducing the sound's environmental impact. Furthermore, this research successfully established an acoustically comfortable prayer room that preserves the tranquility of the surrounding residential areas. Throughout the research process, the use of I-simpa software proved crucial in the design phase, enabling both quantitative and visual acoustic analyses. This approach aids designers in evaluating current acoustic conditions, developing appropriate acoustic treatments, and objectively comparing the effectiveness of various solutions. Utilizing I-Simpa for simulations supports data-driven decision-making rather than relying on assumptions, leading to more accurate, measurable, and communicative design outcomes. This research primarily contributes to the field by presenting a church interior redesign from an acoustic perspective, a topic that has not been thoroughly addressed in previous studies.

## Literature Review

There are specific design requirements for various areas within the church. First, the pulpit is elevated and surrounded by a reflective barrier to effectively project the speaker's voice to the congregation (Doelle, 1972). Second, both the organ and choir are also enclosed by reflective surfaces that minimize echoes, reverberations, and sound concentration. The auditorium space must be designed for clear audibility for the congregation; thus, managing reverberation time requires the inclusion of an acoustic layer in a large auditorium. Additionally, careful control of the coupling spaces—especially in the echo sections—is necessary to prevent disturbances in the main area of the church. Lastly, special attention must be given to creating an environment conducive to meditation and prayer.

The church's spatial organization includes several key areas: (1) The Main Room (Nave), serving as the primary seating area for the congregation facing the altar or pulpit; (2) The Stage (Pulpit), the focal point of worship where the preacher conveys the word of God; (3) The Altar (Communion Table), located at the front of the church for the sacrament of holy communion; (4) The Baptismal Room, designated for baptisms and may consist of a pool or a simple area; (5) Zoning areas in some churches, created for children's activities and other gatherings; (6) The Exterior Zone, which provides a

space outside the church for congregational interaction and circulation; (7) The Prayer Room, typically used for individual prayer or small gatherings; and (8) Various other rooms that serve distinct functions, including offices, multipurpose rooms, and reception areas (Susanto, 2019).

Each room is designed with specific requirements in mind: the pulpit must be elevated and surrounded by a reflective railing to effectively project the speaker's voice to the congregation. Additionally, the organ and choir area should incorporate reflective surfaces to reduce echoes, reverberation, and sound concentration. Furthermore, the auditorium must be constructed to ensure clear audibility for all attendees. Managing reverberation time is essential, particularly in larger auditoriums, which require the use of acoustical cladding. It is vital to control reverberation to prevent any interference with the main church area. Special attention should also be given to cultivating an environment conducive to meditation and prayer (Doelle, 1972).

**1. Acoustics and Noise Criteria (NC)**

Acoustics is the study of sound, which can be categorized into desirable room acoustics and undesirable noise (Satwiko, 2004). Noise criteria refer to the minimum noise level limits established based on the primary function of a space (Indrani & Cahyawati, 2011). In contrast, acceptable noise levels define the maximum noise levels that can remain non-disruptive to activities within a space (Satwiko, 2004).

**Table 1.** Environmental noise standards (Based on Kepmen. LH No. 48/1996)

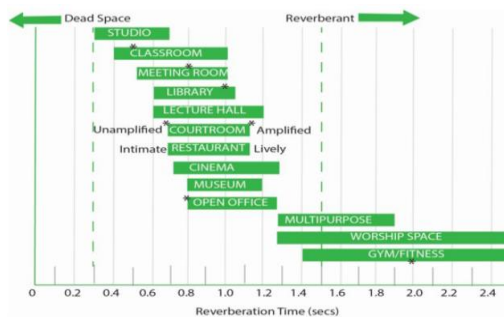
The maximum allowable noise levels for various zones are measured in dBA.

Area/Zone Designation	Maximum Noise Level (dB)
Residential area	55
Trade and service area	60
Office and commercial area	65
Green open space, parks	50
Industrial area	70
Government and public facilities	55
Recreation and public facilities	70
For specific facilities within residential and commercial areas:	
Hospitals/clinics	45
Classroom schools	40
<b>Places of worship</b>	<b>35</b>

Source: <https://ppkl.menlhk.go.id/website/filebox/723/190930165749Kepmen%20LH%2048%20Tahun%201996.pdf>

**2. Reverberation Time**

Reverberation time refers to the sound perception in a closed space caused by the repeated reflections of sound vibrations, even after the primary sound source has stopped (Doelle, Leslie L., 1972). Specifically, it is defined as the duration required for sound intensity to decrease by 60 dB once the sound source has ceased (Indrani & Cahyawati, 2011). This measurement can be easily calculated using I-simpa software, which simplifies the process and eliminates the need for manual calculations; users can simply verify if the reverberation time meets established standards. Reverberation time is crucial for speech clarity. A long reverberation time can reduce speech intelligibility, as overlapping reflected sounds can make voices seem muddled. Conversely, a reverberation time that is too short can create an impression of dullness in the acoustics (Indrani et al., 2007).



**Figure 2.** Reverberation time standard (Source: commercial-acoustics.com)

**3. Interior Materials**

Materials can reflect, absorb, and transmit sound, all of which influence the acoustics of an interior space (Hakim et al., 2024). The choice of materials for floors, walls, and ceilings is critical in acoustics, as it greatly impacts acoustic quality. Therefore, when designing an interior space, it is essential to carefully select finishing materials, as they play a significant

role in determining reverberation time (Kho, 2014). Options for acoustic materials that can affect reverberation time include porous and fibrous absorbent panels, as well as resonance holes.

**Table 2.** Types of acoustic materials

Porous material	Porous materials are highly effective at absorbing sound, transforming incoming sound energy into heat energy within their pores. Examples of such materials include fiberboard, soft plasters, mineral wool, and insulation blankets.
Fibrous material	Fibrous materials can absorb sound across a wide range of frequencies. Examples include mineral wool, which is made from natural or synthetic fibers, such as glass wool and rock wool, as well as carpet.
Panel absorber	Materials for soundproofing or absorption that come in panel form can effectively absorb low frequencies. Examples include wood panels, hardboard, gypsum board, sheets of plywood, and wood panels suspended from the ceiling.
Resonance hole	Hollow resonators serve to enhance the reverberation time (RT) at specific frequencies, particularly at low frequencies.

Source: Mediastika, 2009

#### 4. Absorption Strength

Materials with a high absorption coefficient (near 1) are used to minimize sound reflection, regulate reverberation time, and enhance sound clarity. Conversely, materials with a low absorption coefficient (near 0) are typically used to reflect sound and improve sound projection (Hakim et al., 2024). The table below provides the absorption coefficients used in acoustics for analysis with I-Simpa.

**Table 3.** Sound absorption coefficient chart (125 Hz - 4 kHz)

MATERIAL	THICKNESS	125	250	500	1000	2000	4000
<b>MASONRY WALLS</b>							
Rough concrete		0,02	0,03	0,03	0,03	0,04	0,07
Smooth unainted concrete		0,01	0,01	0,02	0,02	0,02	0,05
Smooth concrete, painted or glazed		0,01	0,01	0,01	0,02	0,02	0,02
Porous concrete blocks (no surface finish)		0,05	0,05	0,05	0,08	0,14	0,2
Clinker concrete (no surface finish)		0,10	0,20	0,40	0,60	0,50	0,60
Smooth brickwork with flush pointing		0,02	0,03	0,03	0,04	0,05	0,07
Smooth brickwork with flush pointing, painted		0,01	0,01	0,02	0,02	0,02	0,02
Standard brickwork		0,05	0,04	0,02	0,04	0,05	0,05
Brickwork, 10mm flush pointing		0,08	0,09	0,12	0,16	0,22	0,24
lime cement plaster on masonry wall		0,02	0,02	0,03	0,04	0,05	0,05
Glaze plaster on masonry wall		0,01	0,01	0,01	0,02	0,02	0,02
Painted plaster surface on masonry wall		0,02	0,02	0,02	0,02	0,02	0,02
Plaster on masonry wall with wall paper on backing paper		0,02	0,03	0,04	0,05	0,07	0,08
Ceramic tiles with smooth surface		0,01	0,01	0,01	0,02	0,02	0,02
Breeze block		0,20	0,45	0,60	0,40	0,45	0,40
Plaster on solid wall		0,04	0,05	0,06	0,08	0,04	0,06
Plaster, lime or gypsum on solid backing		0,03	0,03	0,02	0,03	0,04	0,05
<b>CEILING</b>							
Mineral wool tiles, 180mm airspace		0,42	0,72	0,83	0,88	0,89	0,80
Mineral wool tiles, glued/screwed to soffit		0,06	0,40	0,75	0,95	0,96	0,83
Gypsum plaster tiles, 17% perforated, 22mm		0,45	0,70	0,80	0,80	0,65	0,45
Metal ceiling, 32.5% perforated, backed by 30mm rockwool		0,12	0,45	0,87	0,98	1,00	1,00
Perforated underside of structural steel decking (typical, depends on perforations)		0,30	0,70	0,85	0,90	0,70	0,65
12% perforated plaster tiles, absorbent felt glued to back, 200mm ceiling void		0,45	0,70	0,88	0,52	0,42	0,35
100mm wood/wood slabs on 25mm cavity, pre-screeded surface facing cavity		0,50	0,75	0,85	0,65	0,70	0,70
50mm wood/wood slabs on 25mm cavity, pre-screeded surface facing cavity		0,30	0,40	0,50	0,85	0,50	0,65
100mm wood/wood fixed directly to concrete, pre-screeded surface facing backing		0,25	0,80	0,85	0,65	0,70	0,75
75mm wood/wood fixed directly to concrete, pre-screeded surface facing backing		0,15	0,40	0,95	0,60	0,70	0,60
Plasterboard 10mm thick backed with 25mm thick bitumen							
Plasterboard 10mm thick, perforated 8mm diameter holes 2755m2 14% open area backed with 25mm thick bitumen- bonded fibreglass on 90mm battens	10mm	0,30	0,20	0,15	0,05	0,05	0,05
Plywood, 5mm, on battens 50mm airspace filled with glass wool	5mm	0,25	0,70	0,85	0,55	0,40	0,30
		0,40	0,35	0,20	0,15	0,05	0,05
<b>GLASS AND GLAZING</b>							
4mm glass	4mm	0,30	0,20	0,10	0,07	0,05	0,02
6mm glass	6mm	0,10	0,06	0,04	0,03	0,02	0,02
Double glazing, 2-3mm glass, 10mm air gap		0,15	0,05	0,03	0,03	0,02	0,02
<b>FLOORS</b>							
Smooth marble or terrazzo slabs		0,01	0,01	0,01	0,01	0,02	0,02
Raised computer floor, steel-faced 45mm chipboard 800mm above concrete floor, no carpet		0,08	0,07	0,06	0,07	0,08	0,08
Raised computer floor, steel-faced 45mm chipboard 800mm above concrete floor, office-grade carpet tiles		0,27	0,26	0,52	0,43	0,51	0,58
Wooden floor on joists		0,15	0,11	0,10	0,07	0,06	0,07
Parquet fixed in asphalt, on concrete		0,04	0,04	0,07	0,06	0,06	0,07
Parquet on counterfloor		0,20	0,15	0,10	0,10	0,05	0,10
Linoleum or vinyl stuck to concrete		0,02	0,02	0,03	0,04	0,04	0,05
Layer of rubber, cork, linoleum + underlay, or vinyl+underlay stuck to concrete		0,02	0,02	0,04	0,05	0,05	0,10
5mm needle-felt stuck to concrete	5mm	0,01	0,02	0,05	0,15	0,30	0,40
6mm pile carpet bonded to closed-cell foam underlay	6mm	0,03	0,09	0,25	0,31	0,33	0,44
6mm pile carpet bonded to open-cell foam underlay	6mm	0,03	0,09	0,20	0,54	0,70	0,72
9mm pile carpet, tufted on felt underlay	9mm	0,08	0,08	0,30	0,40	0,75	0,80
Composition flooring		0,05	0,05	0,05	0,05	0,05	0,05
Haircord carpet on felt underlay	6mm	0,05	0,05	0,10	0,20	0,45	0,65
Medium pile carpet on sponge rubber underlay	10mm	0,50	0,10	0,30	0,50	0,65	0,70
Thick pile carpet on sponge rubber underlay	15mm	0,15	0,25	0,50	0,60	0,70	0,70
Rubber floor tiles	6mm	0,05	0,05	0,10	0,10	0,05	0,05
Carpet, thin, over thin felt on concrete		0,10	0,15	0,25	0,30	0,30	0,30
Carpet, thin, over thin felt on wood floor		0,20	0,25	0,30	0,30	0,30	0,30
Carpet, needlepunch	5mm	0,03	0,05	0,05	0,25	0,35	0,50
Stone floor, plain or toiled or granolithic finish		0,02	0,00	0,02	0,00	0,05	0,05
Corkfloor tiles	14mm	0,00	0,05	0,15	0,25	0,25	0,00
Sheet rubber (hard)	6mm	0,00	0,05	0,05	0,10	0,05	0,00
Woodblock/linoleum/rubber/cork tiles (thin) on solid floor (or wall)		0,02	0,04	0,05	0,05	0,10	0,05

Source: <https://www.acoustic-supplies.com>

### Research Methods

This church's interior and acoustic design method employs the design thinking approach. The design thinking methodology is a human-centered, iterative process for creative problem-solving that focuses on users' needs. It typically involves five phases: Empathize (understand the user), Define (articulate the problem), Point of View (analyze the information), Ideate (brainstorm solutions), Prototype (build a version of the solution), and Test (get user feedback). While these steps are often presented linearly, the process is non-linear and flexible, allowing teams to cycle back to earlier stages as needed.

1. Understand: Gain an empathetic understanding of the problem to be solved. This stage employs mind mapping alongside a literature review of design standards and relevant references. The findings from this analysis form the conceptual foundation for subsequent design development.

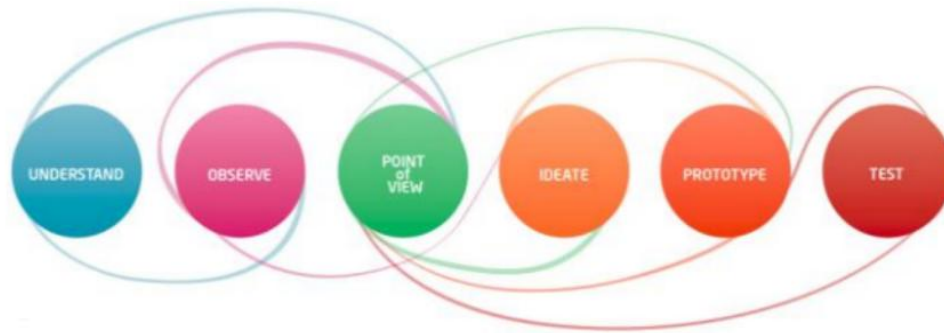


Figure 1. Design thinking methods

2. **Observe:** Collect necessary data through field observations and interviews. This stage commences with thorough field observations aimed at assessing user activity patterns, identifying existing issues, and evaluating the condition of the worship space within the study location. Data collection was conducted through two primary methods: in-depth interviews with the local community to evaluate the acoustic impact, particularly in terms of sound leakage to nearby residences, and the distribution of structured questionnaires to the congregation. Following this, data analysis included room acoustic measurements to identify reverberation issues, as well as a comparative study of similar building typologies serving as reference material. The final stage entails a comprehensive comparative analysis between the reference building and the design object, aimed at producing an optimal design solution that considers both technical aspects and user needs.
3. **Point of View:** Analyze the information to identify the core problem and determine the key issues. This stage commences with thorough field observations aimed at assessing user activity patterns, identifying existing issues, and evaluating the condition of the worship space within the study location. Data collection was conducted through two primary methods: in-depth interviews with the local community to evaluate the acoustic impact, particularly in terms of sound leakage to nearby residences, and the distribution of structured questionnaires to the congregation. Following this, data analysis included room acoustic measurements to identify reverberation issues, as well as a comparative study of similar building typologies serving as reference material. The final stage entails a comprehensive comparative analysis between the reference building and the design object, aimed at producing an optimal design solution that considers both technical aspects and user needs.
4. **Ideate:** Generate ideas for solving the problems by creating design concepts. During the ideate stage, the design is developed as a response to the previously identified problems. This phase involves making design decisions, visualizing the concept, and drafting the final design document through various methods. First, a low-fidelity prototype is utilized to generate alternative layouts, allowing for a comparison of the advantages and disadvantages of each spatial configuration. Second, the 10x10 sketch method is employed to create a schematic design in perspective, accompanied by explanations of the materials to be used. Third, a study model (or study mockup) is constructed to assess the circulation and proportion of the worship space. Lastly, a storyboard is prepared as a medium for presenting the design results to the supervisor, facilitating feedback before finalization.
5. **Prototype:** Develop a tangible embodiment of the concept and design. In the prototype stage, the development of design solutions encompasses three key aspects: decision-making, concept visualization, and final document drafting. This process is carried out through several methods. First, 3D modeling is used to create a visual representation of the design, rendered to convey the atmosphere and character of the space based on the formulated concepts. Secondly, blueprints are prepared, providing a multiview perspective that includes details of interior elements, design features, and furniture specifications. Finally, a physical mock-up is created, serving as a medium for acoustic testing.
6. **Test:** Conduct testing and evaluate the design with the client for further refinement. The test phase is an evaluation stage aimed at gathering feedback on the design outcomes. The evaluation process involves analyzing functional, technical, and aesthetic aspects to ensure the design's quality before it reaches the finalization stage.

## Results and Discussion

### 1. Simulation results and reverberation time optimization using I-Simpa v.1.3.4.

#### a. Church building area

The acoustic analysis revealed that the existing reverberation time (RT) of the church is 4.77 seconds, which significantly exceeds the ideal standard of 1.9 seconds for worship spaces. However, through a comprehensive

acoustic optimization approach, we were able to successfully reduce the RT to 1.92 seconds, thereby meeting the criteria for acoustic comfort. These results illustrate the effectiveness of the design intervention in creating an optimal sound environment for worship activities.

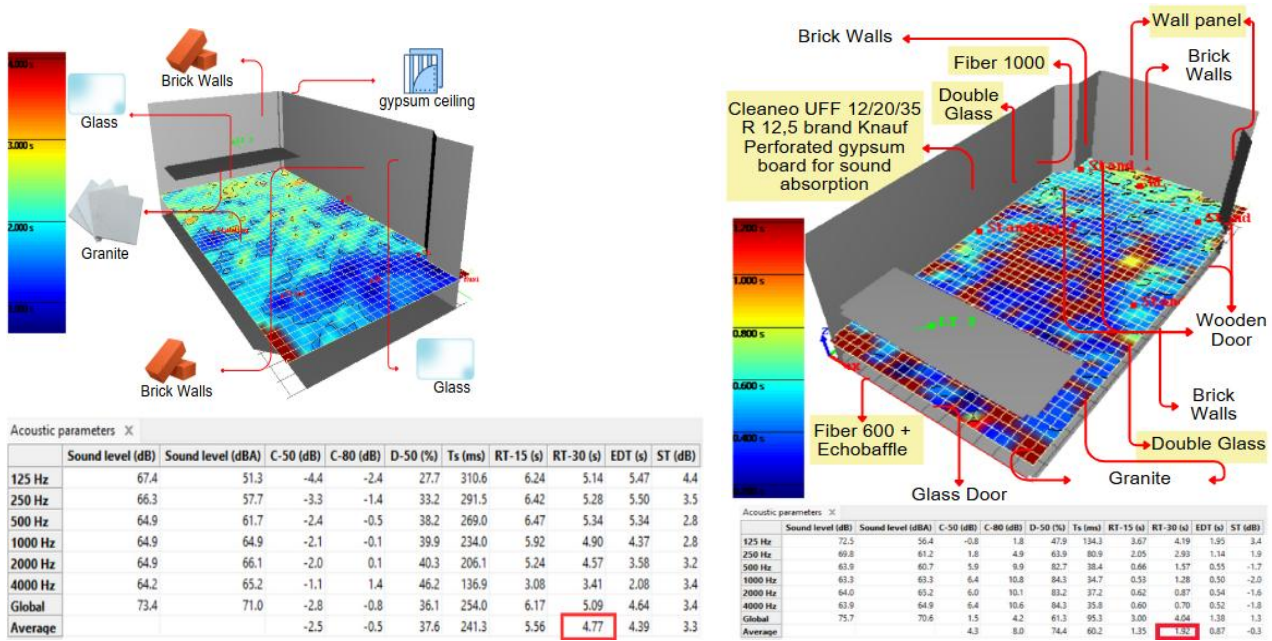


Figure 2. Simulation results and optimization of reverberation time in a church building (Source: document processed by the author, 2025)

b. Multipurpose area

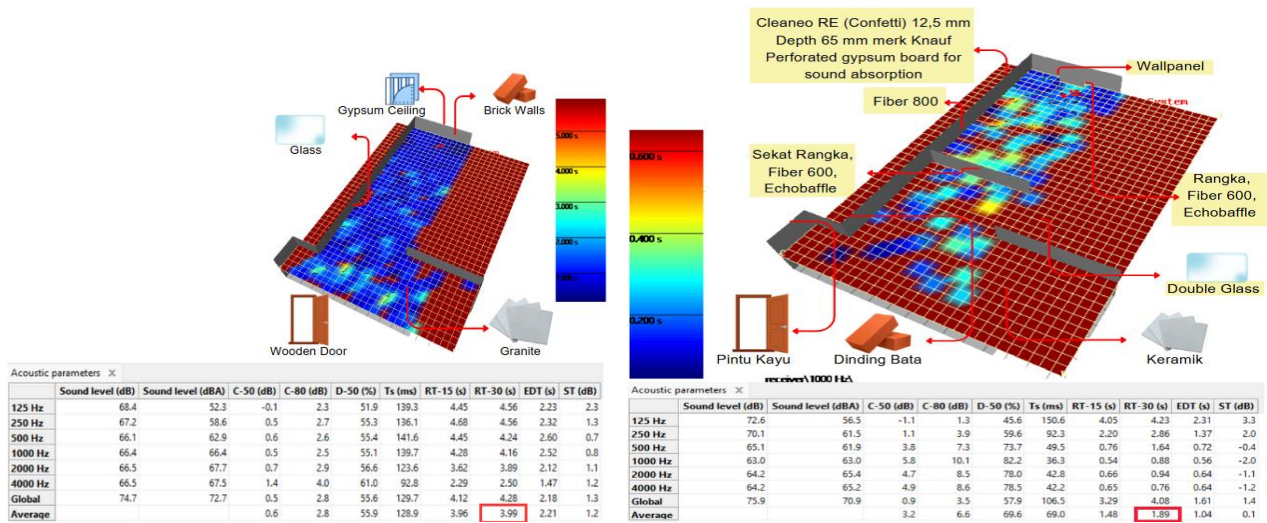


Figure 3. Simulation results and optimization of reverberation time at multipurpose area (Source: document processed by the author, 2025)

Acoustic analysis indicates that the reverberation time (RT) in the multipurpose room, under existing conditions, reaches 3.99 seconds, which exceeds the standard of 1.9 seconds. After implementing acoustic optimization measures, the RT was successfully reduced to 1.89 seconds, meeting the acoustic comfort criteria for multipurpose rooms.

c. Sunday school classroom area

The analysis indicates that the current reverberation time (RT) of 4.99 seconds significantly exceeds the recommended standard of 0.7 seconds. After implementing acoustic optimization, the RT was successfully reduced

to 0.73 seconds, which now meets the standard for children's learning environments. This improvement creates an optimal acoustic setting that enhances sound clarity during Sunday School activities.

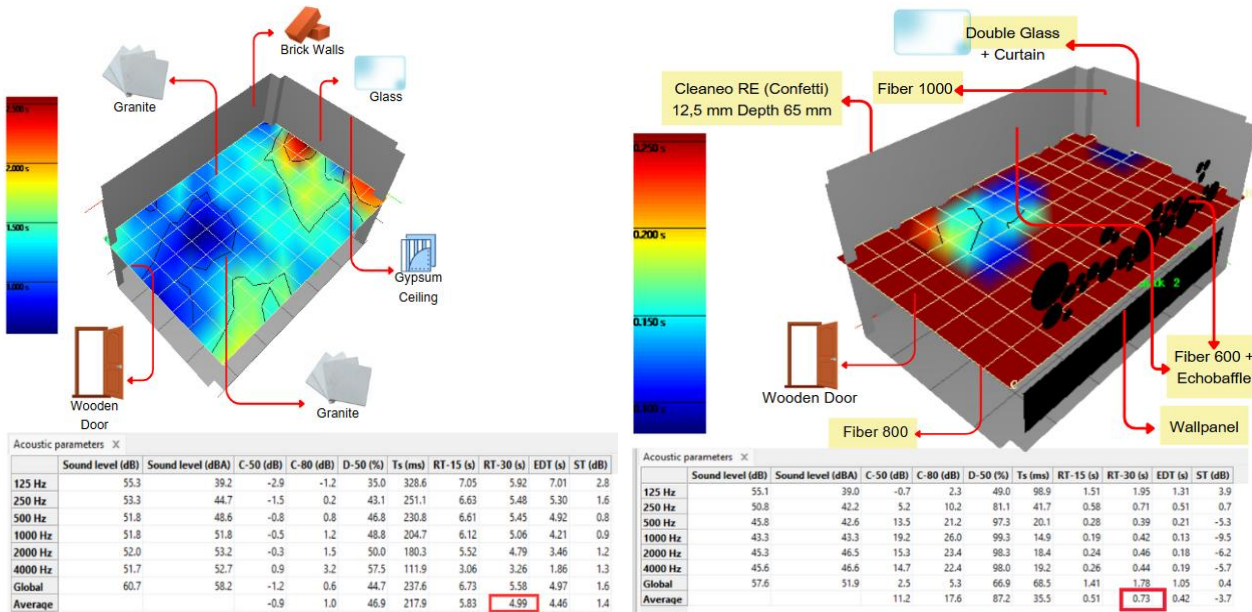


Figure 4. Simulation results and optimization of reverberation time in the school classroom area (Source: document processed by the author, 2025)

d. Office area converted into a teen classroom

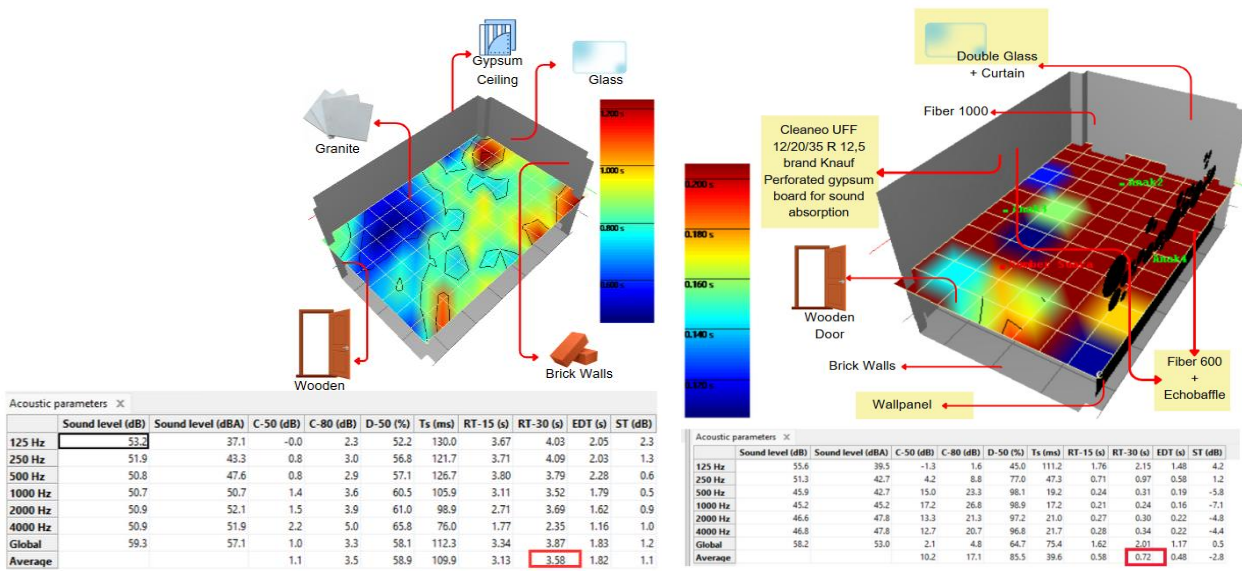


Figure 5. Simulation results and optimization of reverberation time at the office area into a teen classroom (Source: document processed by the author, 2025)

Acoustic analysis revealed that the office space converted into a teen classroom initially had a reverberation time (RT) of 3.58 seconds, significantly exceeding the standard of 0.7 seconds for a learning environment. After implementing comprehensive acoustic optimization measures, the RT was successfully reduced to 0.72 seconds, which meets the acoustic requirements for a teen classroom.

2. Insulation calculations to solve problems that affect churches

The worship area faces challenges not only with sound clarity but also with music that can be heard in the residents' homes in the courtyard. This often disturbs the residents, necessitating sound insulation treatment. Below, you will find

a calculation to determine the appropriate type of insulation treatment to be implemented.

$$\begin{aligned} & \text{STC Outside} - \text{STC Inside} \\ & 100 \text{ dB (motorcycle)} - 35 \text{ dB (worship area standard)} \\ & 65 \text{ dB} \Rightarrow \text{Sapphire-type} \end{aligned}$$

In this Sunday school classroom, there is an issue with noise from motor vehicles entering the space. To address this, we need to improve the wall insulation that faces the road. We have decided to use products from Acourete for this purpose. Below are the calculations for the insulation treatment.

$$\begin{aligned} & \text{STC Outside} - \text{STC Inside} \\ & 100 \text{ dB (motorcycle)} - 40 \text{ dB (classroom area standard)} \\ & 60 \text{ dB} \Rightarrow \text{Beryl-type} \end{aligned}$$

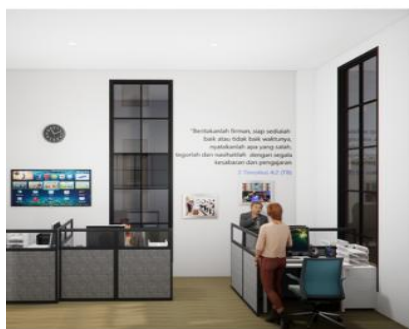
### 3. Design Result of Acoustic Application in Church

In the worship area, the acoustic design aims to create a quiet and comfortable atmosphere for the congregation. The left wall is constructed with Sapphire-type fiber material, which serves as acoustic insulation to help minimize sound transmission to neighboring houses. The right wall, made of brick and finished with paint, offers a clean and simple appearance. At the front of the building, wall panels have been added to enhance the visual appeal. To reduce echo and maintain sound clarity, fiber 600 and echobaffle materials are used at the back of the room. The ceiling is fitted with perforated acoustic panels, while the floor features granite for a modern look and easy maintenance. The glass system is double-glazed, improving sound insulation both from outside and inside. The lighting is arranged using a combination of spotlights and hidden lamps, creating a warm and sacred atmosphere for worship activities.



**Figure 6.** Interior design for worship area  
(Source: document processed by the author, 2025)

This pastoral workspace has been thoughtfully designed to enhance both comfort and productivity for the servants of God. It features ergonomic chairs with lumbar support and work desks that adhere to anthropometric standards. Additionally, a zoning system using partitions has been implemented to ensure privacy.



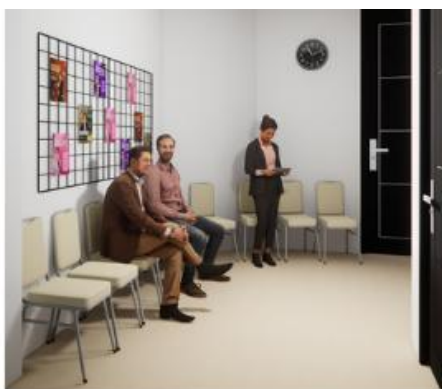
**Figure 7.** Pastoral workspace area  
(Source: document processed by the author, 2025)

This multimedia room is designated for the staff responsible for managing technical needs during worship services, specifically audio and visual operations. It is equipped with two computer units to support presentations and multimedia displays, as well as a sound mixer to regulate sound quality in the worship area. The room is arranged ergonomically to facilitate efficient task performance by the staff. The existence of this space is essential to ensure the smooth operation and comfort of technical aspects during worship.



**Figure 8.** Multimedia area  
(Source: document processed by the author, 2025)

The consistory room serves as a preparation space for ministers before they ascend to the pulpit. This room is designed to be comfortable, fostering a calm atmosphere for prayer or reflection before the service begins. It includes facilities such as a cupboard for storing worship equipment, a mirror for tidying up appearance, and chairs for sitting while waiting for the service to start. The layout of the space is arranged neatly and functionally to create an environment that supports the mental and physical readiness of the ministers before entering the worship area.



**Figure 9.** Consistory area  
(Source: document processed by the author, 2025)

This multipurpose area is designed with acoustic considerations to create a comfortable atmosphere free from noise disturbances. The walls on the right and left sides are made from type 800 fiber material, while the walls in the altar area are covered with type 600 fiber and EchoBaffle to enhance sound absorption. At the entrance of the multipurpose area, there is a partition made of acoustic-absorbing material to minimize sound leakage in and out of the room. To reduce noise from footsteps, the floor is constructed using SPC (Stone Plastic Composite) material, which offers excellent soundproofing capabilities. Additionally, the ceiling features perforated acoustic panels designed to absorb echoes and maintain sound clarity within the space.



**Figure 10.** Multipurpose area  
(Source: document processed by the author, 2025)

The Sunday School classroom area was designed with acoustics in mind to enhance comfort. Echobaffle finishing fiber material is installed on the right and left side walls to minimize sound reflection. The walls with window openings are covered with fiber 1000 using a Beryl-type installation. To reduce noise from footsteps, the floor is made from SPC (Stone Plastic Composite) material, which has soundproofing properties. Additionally, the ceiling features perforated acoustic panels that absorb sound, creating a quieter atmosphere that helps children concentrate during activities.



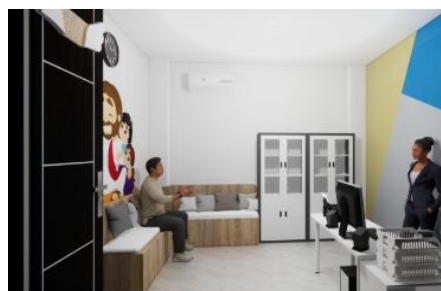
**Figure 11.** Sunday school classroom area  
(Source: document processed by the author, 2025)

The youth classroom area was designed with an acoustic focus to create a comfortable and quiet environment that supports concentration and learning. On the right and left walls, fiber materials and neutral brown echobaffles are installed to absorb sound reflections and reduce echoes. The walls with window openings are coated with type 1000 fiber to enhance the soundproofing of the space. To minimize noise from footsteps, the floor is made of SPC (Stone Plastic Composite) material, which is known for its sound-absorbing properties and durability. Additionally, the ceiling features perforated acoustic panels designed to absorb sound from above and reduce resonance. This design approach aims to create a conducive and effective atmosphere for youth worship, discussions, and learning activities.



**Figure 12.** Youth classroom area  
(Source: document processed by the author, 2025)

The Sunday School storeroom is designated for storing various files and equipment, including stationery and materials needed for Sunday School activities. This room is designed to be organized and easily accessible for Sunday School administrators and teachers. In addition to storage, it is equipped with a computer and printer that can be used for printing or photocopying materials and learning activities. This facility aims to enhance the smooth operation and efficiency of preparing teaching and learning resources for Sunday School.



**Figure 13.** Sunday school store area  
(Source: document processed by the author, 2025)

The women's restroom area features warm white recessed lighting, creating a soft and cozy atmosphere. This lighting choice enhances the room's warm and modern feel. The walls are adorned with brown ceramic materials, which contribute to a natural and elegant touch. Geometric elements serve as focal points in the design, drawing attention and adding aesthetic value to the space. The combination of these lighting elements and wall motifs gives the women's restroom a cleaner, tidier, and more distinctive appearance.



**Figure 14.** Women's restroom  
(Source: document processed by the author, 2025)

This pantry is designed as a storage space for eating and drinking utensils, intended for both public use and Sunday School activities. Its design prioritizes practicality and easy accessibility for users. To ensure durability and a modern appearance, the pantry is constructed using ACP (Aluminum Composite Panel) material, which is known for being durable, lightweight, and easy to clean. This choice of material also creates a clean and tidy impression, aligning with the space's function of maintaining a hygienic and organized environment.



**Figure 15.** Pantry area  
(Source: document processed by the author, 2025)

The men's restroom area is designed with hidden lamps that emit warm white light, creating a bright yet comfortable atmosphere. The walls are adorned with brown ceramic tiles, giving the space a clean and masculine impression. Geometric patterns are featured on specific sections of the walls to enhance aesthetic appeal. In addition to toilets, urinal facilities are provided to ensure comfort and efficiency. This design prioritizes functionality, cleanliness, and a modern, tidy appearance.



**Figure 16.** Men's restroom  
(Source: document processed by the author, 2025)

The boarding house bedroom is designed for comfort and to support optimal rest. This room features a cozy bed, a wardrobe for storing personal belongings, and a mirror for daily grooming needs. The layout of the furniture is functional, ensuring the space feels spacious, clean, and well-organized. Additionally, there is a nightstand for placing personal items as needed. The design of this room prioritizes efficiency and comfort, creating a calm environment that enhances the daily lives of the residents.



**Figure 17.** Boarding house bedroom  
(Source: document processed by the author, 2025)

## Conclusion

This research is driven by the need for a worship space that provides excellent acoustic quality, enhancing user comfort and reducing noise disturbances to the surrounding environment. The interior redesign of the church “Kristus Tuhan Anugerah” successfully employed a holistic acoustic strategy that addresses both insulation and reverberation time control. The acoustic design also prioritizes user comfort by optimizing ventilation, lighting, circulation, and selecting ergonomic furniture. Based on acoustic studies and expert consultations, this design effectively resolves three main issues: (1) The initial reverberation time (RT) did not meet standards due to existing materials that excessively reflected sound. This has now been managed through the installation of specialized absorber materials, achieving RT values of 1.9 seconds in the multipurpose area and church building, and 0.7 seconds in some sections of the Sunday school and youth classrooms; (2) Music sound leakage into the surrounding environment has been significantly reduced through the implementation of Sapphire-type insulation; and (3) The intrusion of motor vehicle noise into the Sunday school and youth classrooms has been mitigated by using Beryl-type insulation on wall elements that could potentially transmit sound. This comprehensive approach not only creates optimal acoustic conditions for worship and church activities but also ensures the comfort of the entire congregation as well as the surrounding community.

One of the most common challenges is selecting acoustic panels. Acoustic panels are an excellent way to enhance the design of any room, and the right acoustic panels can effectively manage noise. Additionally, the coating on acoustic panels simplifies the installation process. It is crucial to remember that not all acoustic panels are the same, so conducting thorough research before investing is essential. This will help ensure you choose the best acoustic panels for noise control while also maintaining an aesthetic room. Higher-quality acoustic panels exhibit greater damage resistance compared to other wall decoration materials, such as curtains and carpets. They are resistant to impact and abrasion, and they seldom peel from the surface or substrate.

The primary contribution of this research is the presentation of a church interior design that incorporates an acoustic approach, a topic that has not been comprehensively explored in previous studies. The design process faced some limitations, particularly in the initial understanding of how the I-Simpa software application functions and the quest for relevant coefficient data to guide the simulations. Additionally, the available tools for testing reverberation time in acoustic modeling are insufficient. Future research is encouraged to focus on modeling reverberation time for acoustic demonstrations and selecting materials that closely resemble those intended for use.

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