Audial comfort optimization of The Lanraki Biringkanaya Makassar Church room

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Abstract. Church is one of the unique worship buildings which is full of audial activities such as speech, songs, and music. The purpose of this research is to evaluate and give redesign suggestions so that the audial comfort in the church room can be achieved. Quantitative research method by analyzing data with the statistically-descriptive. Reverberation time was calculated by the Sabine formula, redesign using Autodesk Ecotect Analysis 2011 program, and the questionnaire processed by IBM SPSS Statistics 25 program. The results conclude that the sound pressure level distribution has been spread evenly, while the background noise and the reverberation time in the church room still exceed the standard. But overall, the user has felt comfort with the condition of the audial church room. So, we made change of materials and furniture that may affect the value of reverberation time and background noise in a room. We hope this research can be a reference to design the next church or similar buildings.

Keywords: audial of the church, background noise, Ecotect, reverberation time, sound pressure level.

1. Introduction

Unlike the auditorium, in the church building, the voice of worship leader needs a touch to be more authoritative and interesting [1]. Because the flows of the sound will determine the quality and quantity of the sound moreover, it is very important to match the wishes of the sound recipient.

The performance of the good audial quality in a room is influenced by the objective factors of the interior design of its enclosure fields (floors, barriers, and ceilings) and dimensions influenced by user capacity. In addition, the using and placement of coating materials is absorptive or reflective that enclose them. So, to achieve the good acoustics, we must pay attention about the material selection and application in a space because both of them playing an important role in creating good audial in a space.

The Lanraki Biringkanaya Church is located at Lanraki Street, Makassar, Indonesia. Nearby Kibaid Church of Batubara Daya and Nurul Iman Mosque and there is Tongkonan above the pulpit in the church room. This make it unique to be research because of the potential noise from the crowd and its material using and complaints by the users that they cannot hear the speech properly so that the further research is needed to evaluate the audial condition in the church room and its redesign suggestions.
2. Literature Study

Most of influential parameters in acoustic room design is reverberation time [2-5]. Reverberation Time (RT) is time range to take a sound energy to decay up to one millionth of its original energy, it is 60 dB. A room that have a long RT will cause decreasing speech intelligibility, because the direct sound is still strongly influenced by the sound reflection. The room with a too short’s RT will impress the "dead room" [6]. According to Egan [7], the optimal RT value for the speech condition in the church is 0,5 – 1,4 seconds and in the music condition is 1,4 – 2,6 seconds. According to Cowan [8], the optimal RT value for contemporary church is 1,4 – 1,6 seconds.

Table 1. Sound absorption coefficient material [9]

| Num | Material             | 125  | 250  | 500  | 1000 | 2000 |
|-----|----------------------|------|------|------|------|------|
| 1   | Brick plaster        | 0.01 | 0.02 | 0.02 | 0.03 | 0.04 |
| 2   | Ceramic tiles floor  | 0.01 | 0.01 | 0.01 | 0.02 | 0.03 |
| 3   | Gypsum board        | 0.29 | 0.10 | 0.05 | 0.04 | 0.07 |
| 4   | Concrete + paint     | 0.09 | 0.07 | 0.01 | 0.01 | 0.01 |
| 5   | Wood ¼” thickness    | 0.42 | 0.21 | 0.10 | 0.08 | 0.06 |
| 6   | Glasses              | 0.35 | 0.25 | 0.18 | 0.12 | 0.07 |
| 7   | Thick glass          | 0.18 | 0.06 | 0.04 | 0.03 | 0.02 |
| 8   | Solid wood           | 0.14 | 0.12 | 0.08 | 0.08 | 0.07 |
| 9   | Plastic              | 0.40 | 0.34 | 0.25 | 0.19 | 0.15 |
| 10  | Speaker              | 0.60 | 0.54 | 0.45 | 0.39 | 0.35 |
| 11  | Steel                | 0.40 | 0.34 | 0.25 | 0.19 | 0.15 |

This is manual calculation of the reverberation time in the church room with the Sabine formula [10]:

\[
RT = \frac{0.161 \cdot V}{A} + A = \sum S \cdot \alpha
\]  

Where,
- \(RT\) = reverberation time (sec)
- \(V\) = volume (m\(^3\))
- \(A\) = total absorbing (m\(^2\) sabins)
- \(S\) = surface material area (m\(^2\))
- \(\alpha\) = material absorption coefficient

Most of large rooms have problems with Background Noise Level (BNL) exceeding the required noise criteria that affects the acoustic performance of the space [11]. Parker said, "noise is sound which is unwanted" [12]. Noise acceptable so that activities and functions in a room is not disturbed, especially in the church room is 35-40 dB [13]. In the worship building requires good acoustics to get a solemn atmosphere [14]. To reach noise acceptable requirement, the research field measurement, analytical calculation, and subjective analysis are necessary. The noise subjectivity
depends on things like environment and conditions, social-culture, and hobbies [15]. The intensity of presence affects the subjectivity of the listener as it relates to adaptation to the conditions [16]. More and more subjects are in certain conditions, the subject will adapt to these conditions. Factors that can affect human hearing's subjectivity are age [17], gender [18], occupation type, listener position, etc.

The placement of the loudspeaker also greatly affects the sound distribution in the space that is not disturb the user's hearing. To know that sound distribution is good in a room, we can measure sound pressure level. Sound Pressure Level (SPL) is the logarithmic ratio of the energy of a sound source with the reference energy source, measured in dB (deciBel). The requirement that the listener can hear the information even in a different position is the difference between the farthest and closest sound level no more than 6 dB. If in a relatively small space where sound sources with normal sound levels have been able to reach the farthest listener, it is almost certain that the sound distribution of the room is evenly distributed [6].

3. Methodology

This study used measurement methods, calculations, and questionnaires. Measurements used Sound Level Meter (SLM) to determine the sound pressure level in a point recorded with a sound effect (so that the measured sound source is stable), and to determine the background noise level in quiet conditions (when there are no people and vehicles around) and crowded conditions (when there are lots of people and vehicles passing by and rain). This is intended to make maximum measurable noise.

The study was conducted in the main room of the Lanraki Biringkanaya Church (figure 1). The area of the church is 29 m x 16.10 m and a capacity of 400 people. The measuring point is divided into 16 points on the ground floor and 9 points on the upper floor (balcony) based on the sitting position of the church in the church room. Specifically for background noise, 17 additional measuring points are located at a location near the opening with a distance of 1 meter from the opening (door, window, stained glass).

Reverberation time is calculated manually with the Sabine formula. Closed questionnaires are distributed according to the measurement point with 5 respondents as sample per measurement point. The contents of the questionnaire include the age, gender of the respondent, and the type of work as these factors can influence the subjectivity of listeners.

The data analysis uses quantitative-descriptive method so that the results of the questionnaire data are used to explain the relationship with the measurement data. After that, the design improvement suggestions are simulated using the Autodesk Ecotect Analysis 2011 program.
4. Results and Discussions

4.1 Sound Pressure Level (SPL)

The shape of the church is symmetrical so that the measured SPL value at the measuring point 3 and 14 is same because the distance to the loudspeaker, the distance to the wall, and the distance to the podium (altar) are same. Similarly at the measuring point 4 and 13, the measuring points 6 and 12, the measuring points 7 and 10, etc. Here is the picture of the symmetrical of that measuring points.

![Figure 4. Symmetrical of the measuring points.](image)

SLM that available for this research only two tools so that the measurement have been doing by putting one SLM closest to the sound source (loudspeaker) and the other was placed in the measuring point. Although on each measuring point can not be measured in the same time, but it is considered more efficient because the measuring result can be matched by adjusting it according to the measured SPL on the loudspeaker. After the sound source has been matched, we can compare it. For example on speaker 1 measured 50 dB, at the same time in measuring point 1 measured 40 dB. While on speaker 2 measured 45 dB, at the same time in measuring point 2 measured 30 dB. So, to make it same with the first data, adding the difference between the SPL of the speakers by adding 5 dB so that on the measuring point 2 the SPL is 35 dB if it is assumed that the sound source is 50 dB.

After measuring on each loudspeaker to check which is loudspeaker dominated the sound that the listener can hear at each measuring point, evidently that only 1 loudspeaker can not be used as a benchmark in measurement because the measured SPL reached only 83,4 dB while the measuring result on 25 measuring point shows the SPL that exceed 100 dB. It means that the loudspeaker did not dominated the sound that the listener can hear on the closest measuring point but the captured sound came from another loudspeaker that it close to the measuring point. So, measurement with this guns sound effect has been doing only on loudspeaker that it close to the measuring point (dominated) except one loudspeaker does not dominated. Here is the SPL measurements with the guns sound effect with the result of its equation to the sound source.
From the table can be easy to compare between the measuring points because it is considered that the sound source was same, 120,2 dB. For checking, it could be seen by SPL on symmetrical measuring point. There was still a little difference due to the time difference as one of the reason so that maybe the SLM shifted by vibration. Although the measurement has been doing on the loudspeakers that dominated, it did not rule out the other loudspeakers also come out the sound so it can affect the value of measurement on the measuring point.

To determine whether the SPL distribution in the space is evenly distributed or not, the farthest and the nearest distance from the sound source were determined. Figure 5 (right side) shows the farthest and closest point by the loudspeaker and the measurement results. The comparison shows that the SPL distribution on the ground floor and balcony of the church was evenly distributed because the difference SPL between the farthest and closest point from the sound source was less than 6 dB. Figure 5 also shows that on point 3 which is in the distance 3,83 meter measuring 110 dB, on the point 2 in 4,89 meter measuring 109,7 dB, and the point 1 in 7,08 meter measuring 106,8 dB.

Similarly, on the measuring point 14, 11, 10 that SPL more lower. More far away from the sound source (loudspeaker), the SPL more lower. It means that the distance affects the SPL, in line with Mills (1976) opinion who told about designing of the acoustic system by setting the listener's distance to the sound source.

Listener response to the audial condition in the Lanraki Biringkanaya Church room can be a comparative data on audial condition previously discussed mathematically so that the questionnaire was used. Here is the comparison of the respond by respondents about the sound condition’s comfort of this church room and the audio repair needed.

Figure 5. SPL comparison on farthest and nearest measuring point by the loudspeaker with guns sound effect.
Figure 6. Comparison graphic of the respondents about the sound condition’s comfortable of the church room.

Figure 7. Comparison graphic of the respondents about an audio repair needed.

Figure 6 shows that respondents who already comfortable about sound condition of this church were 83% or 104 of 125 respondents. While who feel not comfortable just a little, it were 17% or 21 of 125 respondents. It means that users felt comfort about the aural condition of the church room. Figure 7 shows 67% or 84 of 125 respondents said they were not need audio repair and only 33% or 41 of 125 respondents who said needs audio repair in the church room. It means that the users was comfortable with the audio condition of the church room. Here are the cases that arisen regarding to the distribution of SPL in the church.

Figure 8. On the ground floor, there was respondent who requested to do acoustic arrangement that be adapted to all ages.

Figure 9. On the upper floor, there were respondents who can not hear the speech clearly.

Respondent on point 3 was 80 years old, male, and retired. According to the measurement result that on the measuring point 3 the highest SPL (reached 110 dB) and in real condition (before the SPL in all sound sources was equated) the SPL is 108,6 dB. While 105 dB only, can damage the ears within 1 hour. Elderly people was lost their hearing ability in old age or we call presbycusis and the incidence of hearing loss for men is three times higher than for women, it makes sense for respondents to complain that they can not hear well.

Figure 9 shows that on the point 17, 18, and 19 SPL measurement, resulting lower values than measuring point of 20 to 25. Evidently that only respondents in the 19 felt uncomfortable about the loudspeaker arrangement and could not hear the sound of the speech clearly. The measuring point 19 in the rear of the upstairs (balcony) and the measured SPL on the point 19 is the lowest where the real condition (before the SPL in all sound sources was equated) is 94,8 dB. But the lowest SPL on this
point was not reason to make the clearless of the speech because 60 dB only (equivalent to general
conversation) could be heard by normal humans. According to the responses of the respondents, the
intrusion of the speech heard on this point was influenced by outdoor noise and echo speech sound.

4.2 Background Noise Level (BNL)
At the time of worship, sometimes the condition around the Lanraki Biringkanaya Church are very
crowded by children who not following worship and playing, vehicles that passing, and buy-selling
transactions. This church does not use sound proofing material so that allow for leaks of sound
through the pores of space-form elements such as wall and ceiling and there was expansion slits on
windows and doors.

![Figure 10. Layout of the Lanraki Biringkanaya Church with the analysis of its condition.](image)

Figure 10. Layout of the Lanraki Biringkanaya Church with the analysis of its condition.

Here are the comparison graphic between the BNL average in crowded condition and quiet
condition near the opener of church room and on the seats area. According to Koenigsberger (1973),
the noise acceptable for the church room is 35 dB - 40 dB. The value of 69,8 dB exceed 40 dB and the
difference between the crowded and the quiet conditions is 54,2 dB so there was a temporary
suspicion that the church has a sound leaks.

![Figure 11. Slits on the doors, windows, and installation of stained glass became the potential for sound leaks.](image)

Figure 11. Slits on the doors, windows, and installation of stained glass became the potential for sound leaks.

![Figure 12. Comparison graphic between the BNL average in crowded condition and quiet condition near the opener of church room.](image)

Figure 12. Comparison graphic between the BNL average in crowded condition and quiet condition near the opener of church room.

![Figure 13. Comparison graphic of BNL in crowded and quiet condition on the seats area.](image)

Figure 13. Comparison graphic of BNL in crowded and quiet condition on the seats area.
Although the measurement was also doing when quiet condition, but it did not rule out the possibility there was sound like mechanical electrical where the church using AC so that the BNL was not 0 dB. It shows that noise was not only from the outside of the room, but there was also noise in the room. Figure 13 shows that the average BNL in crowded condition was 64.6 dB at the first measurement and 64.7 dB at the second measurement. According to Koenigsberger (1973), the noise acceptable for the church room is 35 dB - 40 dB. This indicates that in crowded condition, the noise was exceed of the comfort standard.

The average of BNL on the seats area in quiet condition is 15.2 dB at the first measurement and 15.0 dB at the second measurement. The sound in the room does not exceed the comfort standard, but the outside sound has been the potential to cause noise for the users. This is seen at the first measurement, the BNL 64.6 dB and 15.2 dB was very far difference, it was 49.4 dB. At the second measurement, the BNL 64.7 dB and 15.0 dB was very far difference, it was 49.7 dB. The difference that too far shows that the noise is caused by the sound leaks so that the sound from outside can enter into the church room.

Potential noise from outside could come from the sound of vehicles on the road, parking area, rain, and settlements. Here are the results of the simulation using the Autodesk Ecotect Analysis 2011 application to explain it.

![Figure 14](image-url)

**Figure 14.** The rays of sound simulation that reflected to the surface with the Ecotect program

Figure 14 shows the sound rays sourced from the loudspeaker, proceed until it reflected to the wall, windows, doors, and stained glass at 40 ms. The reflection result continued until the sound bounced to the surface again on different point. This happened repeatedly until the sound reflection were lost on 300 ms.

It should be noted that a small gap in the wall and ceiling can be formed due to lack of perfect mixture of materials and methods of installation so that the density formed is also less. In the installation of windows, doors and stained glass, cracks are indeed made for the expansion chamber, whereas in the following simulation images there were no gaps in the wall and ceiling or expansion gap. So the results of this simulation shows that if there are no gaps in the wall, windows, doors, and installation of stained glass, a sound leak will not occur. So to insulate sound leaks to reduce background noise, it could be doing by covering the cracks on wall, ceiling, windows, doors, installation of stained glass, or other gaps in the church. Here is the description about questionnaire results compared to BNL.
The inside was not close to the wall is also disturbed, not only on the edge that heard noise from the outside of the room. This is according to the BNL measurement result that each measuring point of the BNL exceed of the standard. On measuring point 5, 10, 17, 22, and 24 were disturbed by outside sound because the respondents were young dominant so their hearing is still very sensitive. On the measuring point 3 and 15 did not felt disturbing by the sound of the outside room because the respondents were elder dominant so that hearing became less. On the measuring point 20 did not felt disturbing by the sound of the outside room although the respondents is dominant still young because around the measuring point 20 there is no window that can be a potential noise and behind the measuring point was still there room so that barried noise from outside.

Table 2. Manual calculation of reverberation time in Lanraki Biringkanaya Church room

| Num | Object       | Material                              | Total area (m²) | Coef. | A    |
|-----|--------------|---------------------------------------|-----------------|-------|------|
| 1   | Wall         | Brick plaster                         | 658.95          | 0.02  | 13.18|
| 2   | Floor        | Ceramic 60x60 cm wood fiber motif      | 510.40          | 0.01  | 5.10 |
|     |              | Ceramic 60x60 cm red blood color      | 23.82           | 0.01  | 0.24 |
| 3   | Ceiling      | Gypsum board                          | 2173.16         | 0.05  | 108.66|
| 4   | Column       | Concrete + paint                      | 10.08           | 0.01  | 0.10 |
| 5   | Main door    | Wood + polinir                        | 6.85            | 0.08  | 0.55 |
| 6   | Side door    | Wood + polinir                        | 5.14            | 0.08  | 0.41 |
| 7   | Glass door   | Clear glass                           | 7.56            | 0.04  | 0.30 |
| 8   | Window       | Wood frame                            | 28.80           | 0.10  | 2.88 |
|     |              | Cloudy glass                          | 31.20           | 0.18  | 5.62 |
| 9   | Stained glass| Wood frame                            | 25.92           | 0.10  | 2.59 |
|     |              | Carving glass                         | 13.20           | 0.04  | 0.53 |
| 10  | Pulpit       | Solid wood                            | 14.15           | 0.08  | 1.13 |
| 11  | MC pulpit    | Solid wood                            | 1.68            | 0.08  | 0.13 |
| 12  | Congregation seat | Solid wood                      | 384.12         | 0.08  | 30.73|
| 13  | Assembly seat| Solid wood                            | 17.46           | 0.08  | 1.40 |
| 14  | Singer seat  | Solid wood                            | 17.46           | 0.08  | 1.40 |
| 15  | Musician seat| Plastic + steel                       | 0.80            | 0.25  | 0.20 |
| 16  | Speaker      | Speaker                               | 25.60           | 0.45  | 11.52|
| 17  | Musical instrument | Plastic + steel                  | 2.56            | 0.25  | 0.64 |
|     |              |                                       | Total A         | 187.31|
|     |              |                                       | Volume          | 2417.32|
|     |              |                                       | Reverb Time (RT)| 2.08  |
However, the noise disturbance did not interfere the users in the church room, as evidenced by the dominant response of felt comfort to the sound condition in the church room and in the comments column only 4% of respondents complain the issue of outside noise. It means they could tolerated such discomfort due to the subjectivity of respondents.

4.3 Reverberation Time (RT)
Here are the tables about manual calculation and computerization result of the reverberation time. Input materials of this computerization based on the materials of the church. Computerization make us be able and easy to see the simulation model and visualization of the church room.

| Table 3. Material input based on Lanraki Biringkanaya Church room material |
|-----------------------------|-----------------------------|-----------------------------|
| Num | Object          | Material | 63 Hz | 125 Hz | 250 Hz | 500 Hz | 1 kHz | 2 kHz | 3 kHz |
|-----|----------------|----------|-------|--------|--------|--------|-------|-------|-------|
| 1   | Wall           | Brick    | 0.10  | 0.07   | 0.03   | 0.12   | 0.02  | 0.02  | 0.03  |
| 2   | Floor          | Plaster  | 0.01  | 0.01   | 0.01   | 0.01   | 0.02  | 0.03  | 0.07  |
| 3   | Ceiling        | Gypsum   | 0.33  | 0.28   | 0.10   | 0.05   | 0.03  | 0.07  | 0.09  |
| 4   | Column         | Concrete | 0.12  | 0.09   | 0.07   | 0.01   | 0.01  | 0.01  | 0.02  |
| 5   | Main door      | Glass    | 0.51  | 0.35   | 0.25   | 0.18   | 0.12  | 0.07  | 0.04  |
| 6   | Side door      | Solid    | 0.17  | 0.14   | 0.12   | 0.08   | 0.08  | 0.07  | 0.06  |
| 7   | Window         | Single   | 0.17  | 0.14   | 0.09   | 0.02   | 0.00  | 0.00  | 0.00  |
| 8   | Stair glass    | Single   | 0.17  | 0.14   | 0.09   | 0.02   | 0.00  | 0.00  | 0.00  |
| 9   | Pulpit         | Solid    | 0.17  | 0.10   | 0.07   | 0.07   | 0.08  | 0.05  | 0.04  |
| 10  | MC pulpit      | Solid    | 0.17  | 0.10   | 0.07   | 0.07   | 0.08  | 0.05  | 0.04  |
| 11  | Seats          | Solid    | 0.17  | 0.10   | 0.07   | 0.07   | 0.08  | 0.05  | 0.04  |
| 12  | Musician seat  | Plastic  | 0.43  | 0.40   | 0.34   | 0.25   | 0.19  | 0.15  | 0.14  |
| 13  | Speaker        | Speaker  | 0.56  | 0.60   | 0.54   | 0.45   | 0.39  | 0.35  | 0.34  |
| 14  | Musical instrument | Plastic | 0.43  | 0.40   | 0.34   | 0.25   | 0.19  | 0.15  | 0.14  |

| Table 4. The simulation result of RT using Ecotect |
|-----------------------------|-----------------------------|-----------------------------|
| Num | Frequency | Total absorptio n | RT(60) |
|-----|-----------|-------------------|--------|
|     | 63 Hz    | 169,426           | 1.87   |
|     | 125 Hz   | 154,352           | 2.01   |
|     | 250 Hz   | 102,192           | 1.92   |
|     | 500 Hz   | 86,455            | 2.04   |
|     | 1 kHz    | 53,913            | 2.43   |
|     | 2 kHz    | 59,003            | 2.06   |
|     | 4 kHz    | 99,451            | 1.76   |
|     | 8 kHz    | 98,447            | 1.46   |
|     | 16 kHz   | 121,693           | 1.38   |

Volume: 2417.32 m³
Seating: 400
Occupancy: 90%

Figure 17. Model of simulation.

Figure 18. Visualization indoor of the church room.
The results of the RT value with manual calculation and computerization has not too different the calculation of manual obtained 2,08 seconds and computerization obtained 2,04 seconds. Thus, these two RT values were matched with the condition in the real building.

Optimal RT value for church in speech condition is 0,5 – 1,4 seconds and in music condition is 1,4 – 2,6 seconds. This shows that the condition of music in the church has met the standard, while the speech condition still needs to be improved. The questionnaire that have been given to church users contains the echo of speech problem. This can be compared to the RT high value in the church room. Here is the description.

**Figure 19.** Position of the respondents who felt disturbed by the speech’s echo (ground floor).

**Figure 20.** Position of the respondents who felt disturbed by the speech’s echo (upper floor).

The green circle is the respondents who felt disturbed by the speech’s echo. The figure shows the pattern formed by the respondent responses of the echo of speech disturbance was almost circular, so that almost every edge of the church room was echo. This maybe due to the reflection of sounds that can be caused by the shape of the space and the surface material of the building elements of the church room. This is also in line with the calculation of the RT value in that room that exceeds the standard of the speech condition so that when the preacher speaks for the next, the sound received by the listener has not finished decaying so that the words of the preacher sound mixed and made the speech was not clear.

Although the respondents said that they were felt comfort about the sound condition in the church room, but the respondents gave complains when looking at certain factors. This happened because the subjectivity of the users as the listeners so they can tolerate the uncomfort they felt.

To achieve audial comfort in the Lanraki Biringkanaya Church room, we could reduce the Reverberation Time (RT) values of that room. Reducing RT value could be doing by modified or added material that has small absorption coefficient with material that has large absorption coefficient. Acoustic simulation using Ecotect program has been doing to get the optimal redesign and according to RT value standard. Various alternatives are suggested so the best alternative can be chosen as an optimize solution and could be applied to the church, which is adaptable and flexible acoustic design. Variables that would be modified or added are materials, dimension of the space-form elements, and furnitures. This is simulation results from several alternative redesign for the church.

The optimal RT value for church in speech is 0,5 – 1,4 sec and in music conditions is 1,4 – 2,6 sec. The intersection of these values is 1,4 sec as to determine the comfortable RT in the church room and achieve the maximum RT value in both functions (speech and music). From the table it can be seen that to achieve a value of 1,4 seconds (no more and no less) is by combine the variables to be modified or added. We could use carpet, plywood, and rockwool as materials that could be reduce RT value. We could change the thickness of the wall and add more seats as dimension and furniture could be
reduce RT value too. This shows that the material, the dimension of the space-form elements, and the using of furniture in a room can affect the value of the reverberation time of that room.

Table 5. Recapitulation of redesign alternatives to achieve optimal RT value

| Variable                        | Redesign alternative                                                                 | Absorption total | RT (sec) |
|---------------------------------|--------------------------------------------------------------------------------------|------------------|----------|
| Material                        | 1. Adding carpet 15 mm on the ground floor.                                         | 167,645          | 1,43     |
|                                  | 2. Adding carpet 15 mm on the ground floor and changing the solid wood doors with the sliding glass doors. | 168,696          | 1,43     |
|                                  | 3. Adding plywood 3/8 inch to the interior wall of the room.                         | 171,020          | 1,43     |
|                                  | 4. Adding rockwool 5 mm to the ceiling.                                              | 170,884          | 1,42     |
| Dimension of space-form elements| 1. Adding the thickness of the wall 1,5 times become 27,5 cm.                        | 175,994          | 1,39     |
| Furniture                        | 1. Adding the number of seats, 60 seats.                                              | 86,455           | 1,39     |
|                                  | 2. Adding upholstered on the seats.                                                   | 168,432          | 1,43     |
| Combination                      | 1. Adding carpet 15 mm on the ground floor and plywood 6 mm on the part of podium wall and the back wall of congregation. | 173,545          | 1,40     |
|                                  | 2. Adding rockwool 5 mm on ceilings and plywood 5 mm on the part of podium wall.        | 174,664          | 1,40     |
|                                  | 3. Adding carpet 15 mm on the ground floor and 6 seats.                               | 167,745          | 1,40     |

5. Conclusion and Suggestions

Regarding to the acoustic condition of the Lanraki Biringkanaya Church room, the distribution of sound pressure levels in the church room was evenly distributed, while background noise level and reverberation time in the church room has not achieved the comfort standards yet. Regarding the user's response to the audial comfort in the church, the users felt comfortable overall. But when looking at the background noise factor and the reverberation time factor, users still complain about the noise from outside of the church room and speech’s echo.

Redesign to create a good design concept in the Lanraki Biringkanaya Church room to achieve audial comfort can be doing by insulating background noise, by covering the cracks on the wall, ceiling, windows, doors, installation of stained glass, or other gaps in the church. Reverberation time insulation can be carried out with a combination of material, the dimension of the space-form elements, and the using of furniture in a church room.

Distance can affect the sound pressure level. In this church, more far away from the sound source, the SPL more lower. The difference of listener position in a room can affect the subjectivity of human hearing.

When we want to build a church or similar buildings, we should be considered the various aspects of audial comfort and potential disturbances that may occur. Using reflective and absorber materials of the sound must be balanced in a room that required optimum audial. The absorption coefficient of the material can be adjusted to the market conditions in order to insert into the Ecotect application so that the simulation results are closer to the truth of redesign. Further research can include variables and parameters that have not been included in this study such as air density that affected by differences of air humidity, air density that affected by differences of height, differences of frequency, early decay time, and clarity.

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