Evaluation of acoustic performance open-plan office at Jawa Pos building based on ISO 3382-3

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Abstract. The acoustic performance of open-plan office has become an important topic for discussion along with the development of office centers in major cities in Indonesia, including in Surabaya. Acoustic problems at open plan office often arise, such as background noise and speech privacy. Based on ISO 3382-3 2012, an open plan office must meet certain standards to keep productivity and concentration. These parameters are Average A-Weighted Background Noise (Lp, A, B), A-Weighted SPL of Speech at 4 m (Lp, A, s, 4m), Spatial Decay Rate of A-Weighted SPL of Speech (D2,s), Distraction Distance (rD), Privacy Distance (rP). From measurement and calculation did to an office building in Surabaya obtained a value of Lp, A, B equal to 52 dBA, Lp, A, s, 4m 52 dBA, D2, S 4,19 dBA, rD 11,75 m, rP 23, 8 m, and STI at the nearest table 0.78. These results indicate that further acoustic treatment is required to meet the standards specified by ISO.

1. Introduction

Acoustics is a rapidly growing topic around the world, especially in big city cities. Along with the proliferation of buildings, buildings, housing with all its uniqueness, it takes a good plan, including in terms of a sound system. Not only concert halls, auditoriums, classrooms, office space also require convenience for increased productivity. In concept and space efficiency, open office space will require less space.

Open plan office was introduced in 1960 by Quickborner Team in Germany. There are many advantages to this office concept, making the office more efficient, efficient place, communication, coordination and easy supervision, and can increase morale.

Open-plan office is currently used for all types of offices, including offices that require high concentration. From here, the concept of open-plan office raises many problems, especially in terms of speech privacy and noise control. Various regulations and standardization were created to address this issue. ISO (International Standard Organization) has published a special standard for open-plan office to be applicable to various types of work with an emphasis on optimal performance. In this study, the evaluation of open office space in Surabaya along with the solution recommendation to improve performance and acoustic comfort for employees can be achieved.

ISO 3382-3: 2012 describes the method of measuring acoustic space in an open-plan office. In it, there are measurement procedures, required equipment, provisions, data retrieval methods, and presentations on reports. This standard is used in medium and large office space. The parameters measured are the distraction distance rD, the decay of D2, S sound, the sound at a distance of 4 meters, and the STI on the nearest work table rP. All these measurements use A (weighting) weighting. Each
point will do 4 values, that is, SPL pink noise \(L_p\), \(L_s\), \(STI\), background noise \(L_p\), \(B\), and distance from the source.

Outside and indoor sounds that appear permanently and stable at some level without the presence of a prominent noise source are called background noise. Measurement of background noise is done first to find out NC (Noise Criteria) a room for each frequency. Speech Transmission Index (STI) is an objective parameter to determine the clarity of the conversations transmitted from the speaker to the listener through the transmission line. The STI method has continued to be developed and improved to date since its introduction in the 70s. Major developments in revising the STI have been made with the International Electro technical Commission (IEC 60268-16) generated in 2011. The conversations are based on how to communicate with people. In many situations, the conversation signal will decrease in the transmission line between the speaker and the listener, which means less clarity of the conversation captured by the listener's ears. To calculate the decrease in sound clarity, a rapid and objective method has been developed, Speech Transmission Index (STI). The STI method applies to certain signals being recovered from the receiver. The quality of STI is derived and expressed at a value between 0 to 1.

| Table 1. Speech Transmission Index (STI) Quality (IEC 60268-16) |
|---------------------------------|-----------------|
| Label STI                        | Nilai STI       |
| Bad                             | 0 - 0.3         |
| Poor                            | 0.3 - 0.45      |
| Fair                            | 0.45 - 0.6      |
| Good                            | 0.6 - 0.75      |
| Excellent                       | 0.75 - 1        |

Based on Table 1, the higher the STI value indicates the better the voice clarity when the acoustic privacy speech is required, the STI value should be low. (Stout, 2015).

In this paper is reported about the acoustic condition of the space of an open office in Surabaya. The acoustic parameters used in the evaluation are background noise, distraction distance, privacy distance, spatial distance, spatial decay rate, and \(L_p\), \(A\), s, \(4m\).

| Table 2. Standard value of open office space based on ISO 3382-3 |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
| No                              | Parameter       | Annotation      | Good            | Poor            |
| 1                               | Background Noise|                | < 50 dB         | > 50 dB         |
| 2                               | Distraction     | STI 0.5         | < 5 m           | > 10 m          |
| 3                               | Privacy distance| STI 0.2         |                |                |
| 4                               | Spatial decay   | Sound attenuation| > 7 dB           | < 5 dB          |
| 5                               | Lp,A,s,4m       | SPL speech 4 m  | < 48 dB          | > 50 dB         |

In part II discussed the methodology, part III contains the results of the evaluation and analysis of parameter values. At the end, the conclusions from the research are presented.

2. Methodology
The room that became the object of research is one open office in Surabaya with the area (34x36 meters.) Figure 1 shows a sketch of the space in the perusal.
In the existing condition, inside the room there are various office supplies, Work Desk (234), Meeting (5), Chair (278), Computer (234), Center stage (1), Lamp 34, (4), Speaker (4), Television (5), scanner (3), Photocopy machine (1), cleaning equipment, Billiard Table (1), Ducting AC (4), Hydrant (4), Plant Pot (4), Hanging Banner (8), Trash Can, Kardus, ATK and Books. Figure 2 shows one corner of the space. The space evaluated appears to be a relatively symmetrical space. Therefore data retrieval can be taken only by a quarter of the office. In accordance with ISO 3382-3 standards, measurements are carried out in length as in line 1 and 2. Figure 3 shows the measurement plan.

Based on Fig. 3, the acoustic parameters are measured, including background noise, distraction distance, privacy distance, spatial distance, spatial decay rate, and Lp, A, s, 4m. Measurements are performed by impulse response as the source of sound and microphone as a listener.

The measurement result is a .wav signal from every microphone position. The measurement signal (recording) is then analyzed using the sound analyzer to obtain the desired acoustic parameters.

3. Result and Discussion
As mentioned in section I, open plan office is a concept of office layout without large divider barrier between employees. Inside a large space lined a desk table is very much placed coincide. In addition to forming a good communication process in the work, there are some negative effects such as noise. Noise can interfere with employee productivity. In this case, a single source of noise will affect many people around it. Fixed noise is background noise mostly caused by AC, computer CPU. Based on ISO 3382-3, the maximum default value for Noise Criteria in open plan office space is 40 dB. If the value exceeds 40 dB, it can disrupt the performance of its employees.
In addition to the above noise, there is also an impulsive or temporal noise, which is caused by the voice of the person speaking. In addition to NC In ISO, the parameters used for evaluation are SPL within 4m (Lp, A, s 4m), and decibel decrease value during multiplication distance (D2, s).

Based on the measurement result, the value of noise criteria as in Figure 4 is obtained.

The height of the background noise in the middle of the picture is caused by the cooling of the room which is flowed through ducting enclosed by aluminum foil. The holes of the ducting are split into two. The possible value of 48 dBA is obtained because it is located just below the ducting, and the right part is not. In the middle, there is also a printing press that sounds quite perceivable. This automatically affects the background noise value.

In the existing condition, in addition to the element of violence of two-way communication voice should also note the value of clarity. If the sound of one of the employees is not audible, then the sound can be categorized as background noise. But if the sound is clear, then the concentration of employees around it will be disrupted, the focus on the work will be distracted by the clear voice. Therefore, please note the distance where the clarity of the sound started badly.

Referring to Table 1, the open plan office parameters are based on ISO 3382-3, there are parameters that need to be obtained is distraction distance (rD) where STI = 0.5 and privacy distance (rP) where STI = 0.2. In addition, it is also necessary to measure the STI on the nearest workbench. A decreasing SPL against the increase in distance. From here it can be done plotting the graph decrease the voice level of the conversation to the distance. Then obtained Figure 4 as follows.

![Figure 4. SPL graph of distance on Line 1](image)

For the open-plan office, the recommended STI value is where it is located less than 10 meters away for STI = 0.5. The image also shows the trend line formed from the point of test point on line 1 and 2 which is done separately.

Based on Figure 5, for the distance distraction (distraction distance) line 1 is at a value of 9.68 meters. While on line 2 is at a distance of 13.69 meters. From here it can be analyzed that line 1 still meets the standards and line 2 does not meet. Viewed from the side of the slope line is also known in
line 2 is very gentle with the equation of the line $y = -0.0223x + 0.8061$. When the STI on the nearest table is 0.8 it is necessary to have a value $b$ below 0.028 to achieve STI 0.5 before the distance of 10 meters. As in line 1 which has a slope of the limit, but still meet the standards of open plan office requirements.

Figure 5. STI graphs at each measurement point line 1 and line 2

The uniqueness of open plan office design has a difference of roof height. At the edge has a height of 4 meters while in the middle has a height of 8 meters. To the lower edges because there are another office space and balcony. With the condition of the curved balcony as in Figure 6 below.

Figure 6. Microphone position and speaker at open-plan office

Viewed from the side position as in Figure 6, line 1 on the left and line 2 on the right. Line 1 is farther from the right wall, and line 2 is closer to the right wall. Line 1 has a border roof between 8 meters and 4 meters, while Line 2 has a roof of 4 meters. Automatically the reflection of sound received by line 2 will be bigger and faster from the direction of the right wall and roof. This large reflection will make the SPL decline run very slowly and the clarity of the sound is higher. So the slope difference of STI graph to distance on line 2 is more sloping than line 1.

From Figure 6, the SPL graph of the above distance, on line 1 obtained the value at a distance of 4 meters of 51.8 dB and doubling the distance of 3.69 dB. In line 2 we get a value of 4 meters at 52 dB and a doubling of 4.02 dB. For this SPL measurement ISO cleans good standard of 48 dB for a distance of 4 meters. The value is obtained because expected normal human voice has decayed at that distance. And below the standard background noise that is worth 50 dBA on All Frequency. With these results then there is still a little voice perceived.

Direct measurement results show that there are still many deficiencies in the value of predefined parameters. Therefore it is necessary to improve the acoustic condition of the room in the simulation.
To know the value of improvement, to be a more precise target and efficient then conditioned the first result of simulation which refers to the result of measurement directly. After the two are equated, some improvement plans are made possible. Briefly, the high background noise value is mainly due to the central air ducts. Then the repair will be tried with the installation of the absorber on the ducting AC. Speech levels that have low attenuation are caused by a long drone. The buzz is due to the number of reflections in the room. Then the number of reflections resolved by the absorber laid on the ceiling of the office. The STI value is also problematic will be better after adding the absorber on the work table. The addition of sound masking on each work table will also worsen STI in the place.

4. Conclusion

Along with the development of acoustics in developed and developing countries, the acoustic object of open-plan office space needs to be applied also especially in big cities like Surabaya. The conclusions obtained from this research include:

1. Background Noise (background noise) is still not meet the standards, especially those under ducting AC. Therefore it is necessary to install a foam-based noise absorbers on the ducting.
2. The voice level of the conversation is at a distance of 4 meters of 51.8 dBA. The number is still not meet the standards because it can still be felt the difference with the background noise limit. While the attenuation of the sound of 3.69 dBA on line 1, and 4.02 dBA on Line 2. also less meet the 5 dBA limit standard. Therefore it is necessary to do the treatment in the form of the addition of absorber layer made of blanket in the sky of the room sky.
3. Distraction distance is at a distance of 9.7 on line 1. While on line 2 is 13.7 dBA. For Line 2 less meet. In addition to the addition of blankets in the sky, also need to be added silencer on the workbench.
4. Sound masking also needs to be prepared and activated conditionally to disguise the clarity of other voice conversations while interrupting the work concentration.

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