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Simulation of Several Open Plan Office Design to Improve Speech Privacy Condition without Additional Acoustic Treatment

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Abstract

As a result of having low partitions between workstations, most of the open plan offices have poor speech privacy conditions. Utilization of high-cost acoustic treatment usually is necessary to improve this condition. In order to increase the speech privacy without increasing the installation cost, the acoustical condition can be optimized by re-arranging the office layout through computer simulation. Referring to the guidelines of measurement set-up and calculation as derived in ISO 3328-3:2012, ray tracing simulation has been conducted to find this optimum condition. Results on this paper show that the acoustical condition can be improved through layout, workstation, or screen partition modification.

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Keywords: Open-plan offices; speech privacy improvement; ISO-3328-3:2012

1. Background

Open plan office is a type of office that utilizes one large room to be occupied by many workers in one office. Screen partitions are usually used on each workstation to create a confined working space. The advantages of this kind of office are cheaper construction fee, lower energy usage for air-conditioning and lighting. In addition to well-designed open plan office, it improves communication between workstations. In open plan office, easier idea exchange and more convenient conversation can be favored (Zahn, 1991). On the contrary, when open plan office is

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not well designed acoustically, noise such as speech and laughter, phone ringing tones, footsteps, ventilation noise, appliances noise, cleaning noise, etc. become distractions inside the office. Several works have been done on those subjects, such as (Bradley, 2003), and (Veitch et. al., 2002).

According to Haapakangas (Haapakangas, Haka, Keskinen, & Hongisto, 2008), speech is experienced as the most disturbing sound among other sounds in the open-plan office. Lack of speech privacy between workstation can cause deterioration of the cognitive performances. Serial recall (e.g. arithmetic calculations) and complex working memory task (e.g. words memorizing) are examples of such activities that can be deteriorated. From his findings also, it is shown that enhanced effort on reading is happening when low speech privacy happens. For this reason, it can be concluded that low speech privacy condition is related to the low working performance in an open-plan office.

To handle this problem, acoustic treatment is usually applied to the surfaces of open-plan office to get better acoustics condition. The treatment can be done using sound absorbing materials or sound diffuser. This treatment, however, increase the construction cost and, therefore, it is not preferred. To compromise this situation, the selection or modification of the office layout, the workstation types, and the height of a partition can be chosen to get a better speech privacy. The acoustics condition for the open-plan office designed can be analyzed using computer simulation before the construction stage. From simulation results, several design alternatives of the open-plan office can be obtained with the best speech privacy condition. The idea of using computer simulation to analyze open plan office is introduced by Rindel (Rindel, 2012), where commercial software based on ray-tracing acoustic was used to obtain several parameters of open-plan office. In this paper, the simulation of several open-plan offices with modification scenarios were studied; the modification is based on workstations layout, the workstation type, and the workstation partition heights. These scenarios are the extension of the work that was conducted by Sarwono (Sarwono, Larasati, Soelami, & Sihar, 2013) regarding the modification of acoustical condition of open plan office based on workstation layouts.

2. Research design

To determine the speech privacy condition of an open-plan office, quantities and measurement guidelines have already been standardized in ISO 3328-3:2012. These quantities indicate the general acoustical performance of open-plan offices. There are 5 parameters derived in this guidelines: STI to the nearest workstation, distraction distance (r_D (meters)), privacy distance (r_P (meters)), SPLA spatial decay rate ($D_{2,S}$ (dBA)), and SPLA at 4 meters ($L_{p,A,S,4m}$ (dBA)). The calculation details of the parameters can be seen in the related standard. In this paper, simulations that imitate the measurement condition in ISO 3328-3:2012 were conducted using the commercial software CATT-Acoustic where ray-tracing and image source method are used as the algorithm of the simulation.

2.1. Simulation condition

The simulations were conducted for three scenarios to improve the room acoustic condition:

- Simulations of 4 workstation models in the same layout arrangement.
- Simulations of 4 workstation layouts arrangement.
- Simulations of 4 workstation screen heights of the same layout arrangement.

The scheme of the office geometry will be further explained in each subsection. In all the models, an omnidirectional source with sound pressure level of 57.4 dBA at 1.0 m distance, and normal effort unisex speech as seen in Table 1 is used. A 35.8 dBA background noise was also given to mimic the condition in an open- plan office where the characteristics are given in Table 2. In each simulation, source and receiver positions were located at 1.2 m height from the ground, 0.5 m from the edge of the workstation tables, and at least 2 m from the closest wall. The number of receiver points was varied between 4-5 points. Based on ISO 3328-3: 2012 guidelines, the path of the measurement points is divided into a non-straight measurement and straight measurement path. The STI values and A-Weighted SPL of speech for each position were determined from all simulations of the scenarios. From the obtained STI, relation between STI and the source-receiver distance can be interpolated by a regression model to get distraction distance and privacy distance and STI of the nearest workstation. Meanwhile, from spatial sound distribution of A-weighted SPL of speech, the spatial decay rate of speech and A-weighted SPL of speech at 4 m can be obtained.

Table 1. Normal effort unisex speech characteristics

Frequency (Hz)	125 Hz	250 Hz	500 Hz	1kHz	2kHz	4kHz
SPL at 1 m from source at free field/ $L_{p,S,1\,m}$ (dB)	50	54	58	52	44,8	38,8
A_i-Weighting (dB)	-16	-9	-3	0	1,2	1

Table 2. Open-plan office background noise characteristics

Frequency (Hz)	125 Hz	250 Hz	500 Hz	1kHz	2kHz	4kHz
Background Noise (dB)	45	38	32	28	25	23

For each scenario, several absorption conditions of the open-plan offices are given in Table 3. Material or object usage is different from each scenario.

Table 3. Absorption coefficients for open-plan office simulation

Material / Object	Absorption Coefficient (%)					
	125 Hz	250 Hz	500 Hz	1kHz	2kHz	4kHz
Thick Carpet backed by a wall (Floor Plane)	2	5	14	37	50	65
Thick Carpet (Floor Plane)	9	8	21	27	27	37
Thick Window (Wall Plane)	18	6	4	3	2	2
Concrete (Wall Plane)	1	2	2	3	4	5
Acoustic tile (Ceiling Plane)	70	66	72	92	88	75
Wood Workstation Type 1	15	19	22	39	38	30
Wood Workstation Type 2	28	22	17	9	10	11
Metal Furniture Storage unit	76	76	90	99	85	70

2.2. Improvement scenarios by modification of workstation models

In the 1st scenario, four workstation models for an open-plan office were simulated. This office capacity is 58 persons with the layout shown in Figure.1. The material inside the office includes the wood workstation model 1 (Figure 2a), three metal furniture storage units (purple color in Figure. 1), a thick carpet, wall plane, and ceiling plane. Data of materials can be seen in Table 3. The dimensions of the room are 2.75 m height, 12 m wide (y-axis), and 29 m length (x-axis). Four workstation models have 1.22 m height, where the scheme and dimensions are shown in Figure.2.

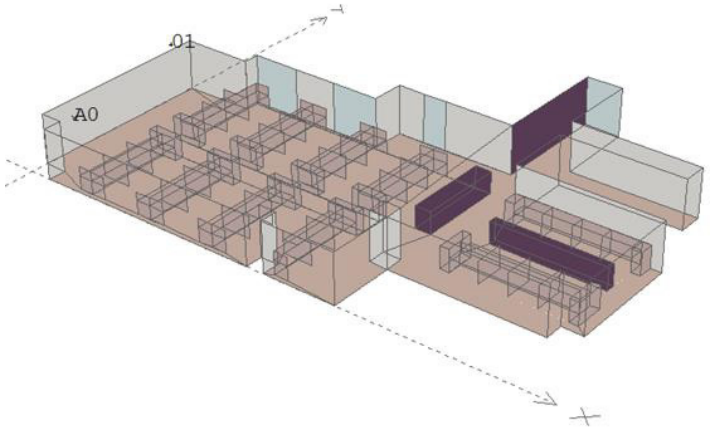

Fig. 1. Basic scheme of the open-plan office.

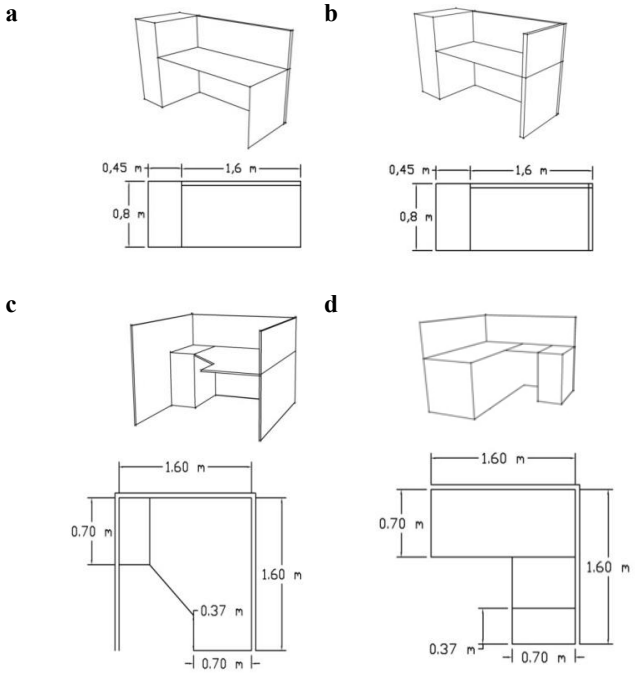

Fig. 2. Workstation models of open-plan office (a) model 1; (b) model 2; (c) model 3; (d) model 4.

2.3. Improvement scenarios by modification of workstation layout

In the 2nd scenario, three workstation layouts of the open-plan office using the same workstation models are simulated. The office has a capacity of 36 persons, where dimensions of the room are 2.75 m height, 13.3 m wide (x-axis), and 22.16 m length (y-axis). Figure 3 describes the scheme of 3 layouts. All layouts were set using the same workstations.

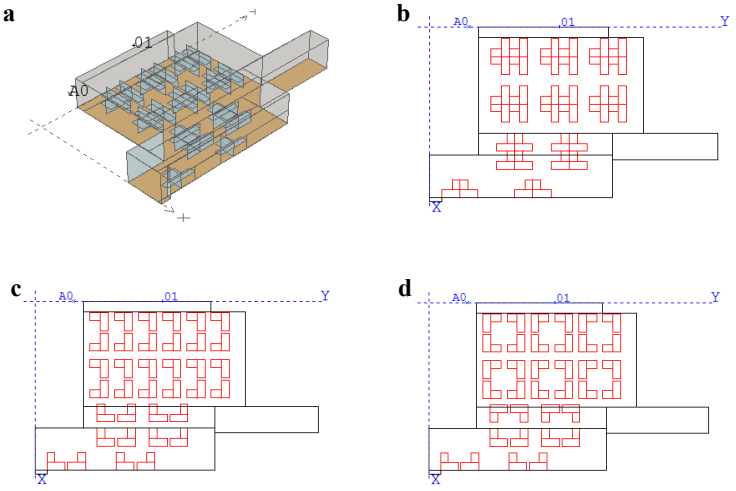

Fig. 3. Open-plan office with three types of layout arrangements of workstations (a) office basic scheme; (b) Layout 1; (c) Layout 2; (d) Layout 3.

2.4. Improvement scenarios by modification of workstation partition heights

In this scenario, four partition heights (1.22m - 1.5m) are used in the same open-plan office layout and the same workstation type. The workstation scheme can be seen in Figure 4.a where the default height of the partition is 1.22 m, and the basic scheme of the open plan office can be seen in Figure 4.b.

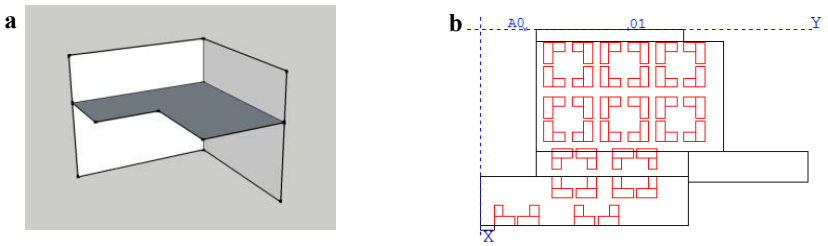

Fig. 4. Workstation model and layout for modification of a workstation screen heights (a) Workstation model; (b) Workstation Layout.

3. Results and discussion

3.1. Results on modification of workstation models

The results from the straight and non-straight measurement path simulations have indicated that the workstation model 3 and 4 are the best candidates to create a better speech privacy condition. Among them, the model 3 has a better acoustics condition as we compared all the parameters mentioned earlier. In these results, it can be seen that the existence of the partition on all sides of a workstation can improve the STI for the nearest workstation and reduce the distraction distance. In the non-straight path it can be seen that model 4 has an interesting characteristics, where the distraction distance and STI of the nearest workstation are the lowest, but among others, it has the longest privacy distance. This characteristic can be propagation.

Table 4. Results on modification of workstation models

Parameters	Straight Path Measurement				Non-Straight Path Measurement			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
STI at the nearest workstation	0,7	0,7	0,6	0,8	0,7	0,7	0,5	0,5
Distraction Distance	6,1	6,1	5,7	6,1	8,5	8,4	6,6	6,2
Privacy Distance	14,0	13,6	13,6	11,6	12,0	12,1	15,2	22,9
Spatial Decay Rate of Speech SPL-A	-3,6	-3,6	-3,4	-3,9	-4,6	-4,6	-3,0	-3,3
Speech SPL-A at 4 meters	41,7	41,5	42,6	44,3	48,9	48,4	41,5	42,7

3.2. Results on modification of workstation layout

Based on the acoustic parameters, it is shown that the speech privacy condition can be improved through the layout out of the workstation, even though, the same workstation model is used. With regards to the privacy distance, distraction distance, and decay rate, the layout model 3 has the best speech privacy compared to the other model. In contrary, layout model 3 also has the highest STI at the nearest workstation and high Speech SPL-A at 4 meters. These occurred due to the non-existence of partition between source and receiver. Both functionally and acoustically, this layout model is the best for occupants that work in groups. Each group can carry out discussion privately without distracting other groups within the same office.

For workstation or office that need high cognitive performance, the speech privacy condition in layout model 3, is not suitable. Instead, layout model 1is suggested for this type of office since from two measurement paths, the STI of the nearest station has lower values.

The results of the straight and non-straight measurement path simulations have shown that workstations model 3 and 4 are the best candidates to create a better speech privacy condition. Among them, the model 3 has a better acoustics condition based on the parameters. Given these results, it can be seen that the existence of the partition on all sides of a workstation can improve the STI at the nearest workstation and reduce the distraction.

Table 5. Results on modification of workstation layout

Parameters	Length Measurement Path			Width Measurement Path		
	Layout 1	Layout 2	Layout 3	Layout 1	Layout 2	Layout 3
STI in the nearest workstation	0,66	0,61	0,88	0,76	0,93	0,91
Distraction Distance	7,9	7,0	6,4	8,7	9,1	7,1
Privacy Distance	21,6	22,7	11,8	15,9	15,7	13,2
Spatial Decay Rate of Speech SPL-A	3,0	3,0	4,4	4,1	4,4	4,3
Speech SPL-A at 4 meters	47,5	46,2	50,0	50,1	51,5	50,6

3.3. Results on modification of workstation partition heights

In this scenario (see Table 6), there is no trend of STI variation on each increment of the partition heights. Distraction distance and privacy distance has a correlation only for a wide measurement path but in overall, the 1.5 m partition height has the best speech privacy condition. However, this does not mean that a larger screen partition will create a better speech privacy condition. This condition is probably caused by the drawback of the ray tracing method due to the inability to model the sound wave diffraction phenomena (Elorza, 2005). Further studies on this matter should be conducted.

Table 6. Results on modification of workstation partition heights

Parameters	Length Measurement Path				Width Measurement Path			
	1,22m	1,3m	1,4m	1,5m	1,22m	1,3m	1,4m	1,5m
STI in the nearest workstation	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9
Distraction Distance	6,4	7,0	6,7	6,5	7,1	7,1	6,9	6,5
Privacy Distance	11,8	12,7	12,1	11,7	13,2	12,6	12,3	11,4
Normal Speech SPL Spatial Decay	4,4	4,4	4,5	4,6	4,3	4,4	4,4	4,5
Normal Speech SPL 4 meters from the so	50,0	50,1	49,6	48,9	50,6	50,1	50,3	48,9

4. Conclusions

Simulation of several open-plan offices to evaluate speech privacy parameters has been conducted. The modification of the workstation layout and the workstation model can improve the acoustic condition of the open-plan offices. However, the findings have shown that the height increment of the workstation's partition does not improve the acoustical condition. It was expected that by increasing the height of a partition, it would result in gradually improvement of the speech privacy.

The variations of the privacy distance, distraction distance, and the STI values of the nearest workstation shows that one type of an office layout suits best for a number of people working as group, while the other type of layout is suitable for private working office. In addition, each speech privacy parameters should be carefully observed since the physical interpretation will give different conclusion of speech privacy condition.

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References

Bradley, J. S., (2003). The Acoustical Design of Conventional Open Plan Offices, *Canadian Acoustics*, *31*. 23-31.

Elorza, D.O. (2005). *Room acoustics modeling using the ray tracing method: implementation and evaluation*, Licentiate Thesis, Department of Physics, University of Turku, Finlandia.

Haapakangas, A., Haka, M., Keskinen, E., & Hongisto, V. (2008). Effect of speech intelligibility on task performance an experimental laboratory study, 9th International Congress on Noise as a Public Health Problem. Conneticut, USA.

International Organization for Standardization. (2012). ISO 3382-3 acoustics - measurement of room acoustic parameters part 3: open-plan offices.

Rindel, J. H. (2012). Prediction of acoustical parameters for open plan offices according to ISO 3382-3, Proceedings The Acoustics 2012, Acoustical Society of America. Hongkong.

Sarwono J., Larasati A. E., Soelami F.X.N, & Sihar. I. (2013). Speech privacy distance in 3 open-plan office layouts : computer modelling and simulation approach, International Congress on Sound and Vibration 20. Bangkok, Thailand.

Veitch, J. A., Bradley, J. S., Legault, L. M., Norcross, S., & Svec, J. M. (2002). *Masking Speech in Open-Plan Offices with Simulated Ventilation Noise: Noise Level and Spectral Composition Effects on Acoustic Satisfaction.* IRC Internal Report, IRC-IR-846.

Zahn, L. G. (1991). Face to face communication in an office setting: the effects of position, proximity and exposure. *Communication Research*, *18*. 737-754.