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Room Acoustic design in open-plan offices

Erling Nilsson[a]
Saint-Gobain Ecophon AB, Box 500 SE-260 61 Hyllinge, Sweden

Björn Hellström[b]
AF-Ingemansson AB, Box 47321, SE-100 74 Stockholm, Sweden

ABSTRACT

In a Nordic cooperation project the acoustical conditions in open-plan offices was investigated. Measurements have been carried out in five open plan offices accompanied with an inquiry gathering the subjective judgments by the staff. A program for the acoustical measurements was designed specifying how to perform the measurements and which type of parameters to measure. The acoustical parameters included in the measurements are Reverberation time T20, Early Decay Time (EDT), Clarity (C50), Speech transmission index (STI), Speech intelligibility index (SII), Privacy Index (PI), Rate of spatial decay of sound pressure levels per distance doubling (DL_2), Excess of sound pressure level with respect to a reference curve (DL_f), background noise levels in occupied and unoccupied offices. In two of the offices a refurbishment program was carried out. Measurements as well as questionnaire were accomplished after refurbishment. The effect on room acoustic parameters DL_2 and DL_f and on subjective judgments by the staff will be presented in this paper.

1. INTRODUCTION

Nowadays the open-plan offices have become a common work environment for many people. When sharing the same floor area high demands on the planning and the acoustical treatment of the offices has to be fulfilled for creating a functional work environment. In an open-plan office the activities often means communication between team members but also concentrated work. The acoustical design should support both these activities. In the planning process and also for verification of the acoustical conditions there is a need for efficient room acoustic methods. It's recognized that the reverberation time alone as a global parameter is insufficient to reveal the acoustic conditions in open-plan offices[1-3]. For an appropriate acoustic design it is important to consider the activities going on and the type (shape/diffusivity) of the room. Further, the fact that the hearing is a multi dimensional experience several room acoustic parameters are needed for an evaluation that is related to the subjective impression of the acoustic conditions. Thus, for different room types and activities different room acoustic parameters will be of more or less importance[4]. Taking into account the human perception of sound, the room type, and the activities going on, the probability of a successful acoustic design will increase. In open-plan offices measures related to the spatial behavior of sound propagation seems to be well suited for the acoustic characterization[5]. These types of measures were suggested in a first draft of a standard for acoustic evaluation of open-plan offices[6]. In a Nordic cooperation project the conditions in five open-plan offices were investigated both by room acoustic measurements and by inquiries among staff. In two of the offices a refurbishment program was settled. After

[a] Email address. erling.nilsson@ecophon.se
[b] Email address. Bjorn.Hellstrom@afconsult.com

refurbishment measurements and inquires was performed once more. The aim of this paper is to present the acoustic treatments effect on suitable room acoustic parameters and on the subjective impression.

2. METHOD

A. Measurement specification

The acoustical parameters included in the measurements are Reverberation time T20, Early Decay Time (EDT), Clarity (C50), Speech transmission index (STI), Speech intelligibility index (SII), Privacy Index (PI), Rate of spatial decay of sound pressure levels per distance doubling (DL_2), Excess of sound pressure level with respect to free field (DL_f), background noise levels in occupied and unoccupied offices. In this paper we will focus on the parameters DL_2 and DL_f. The meaning of these measures is illustrated in figure 1. Reverberation times and speech transmission index were measured at workplaces while DL_2 and DL_f were measured at two different paths, one along the workplaces and one in the diagonal direction of the room. This illustrated in figure 2.

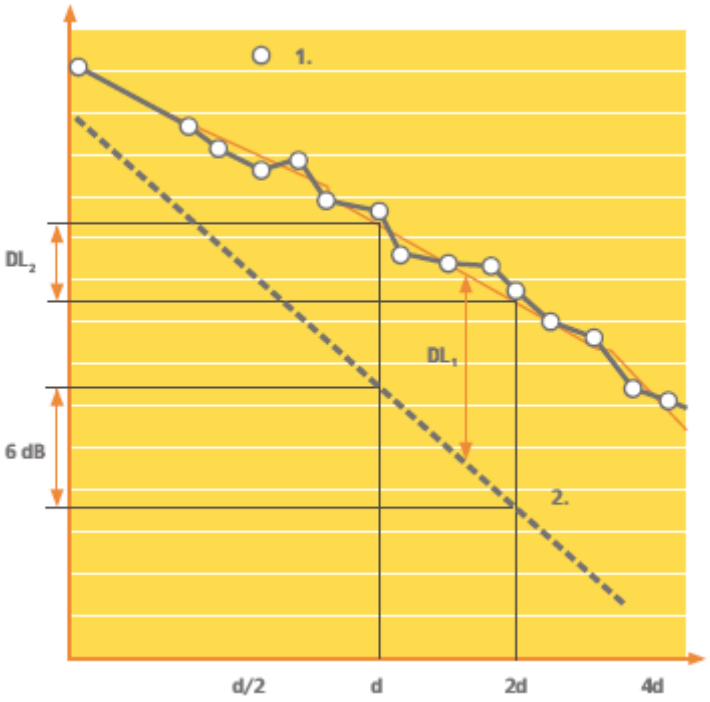

Figure 1. 1) Sound pressure level at different distance from sound source
2) Free field

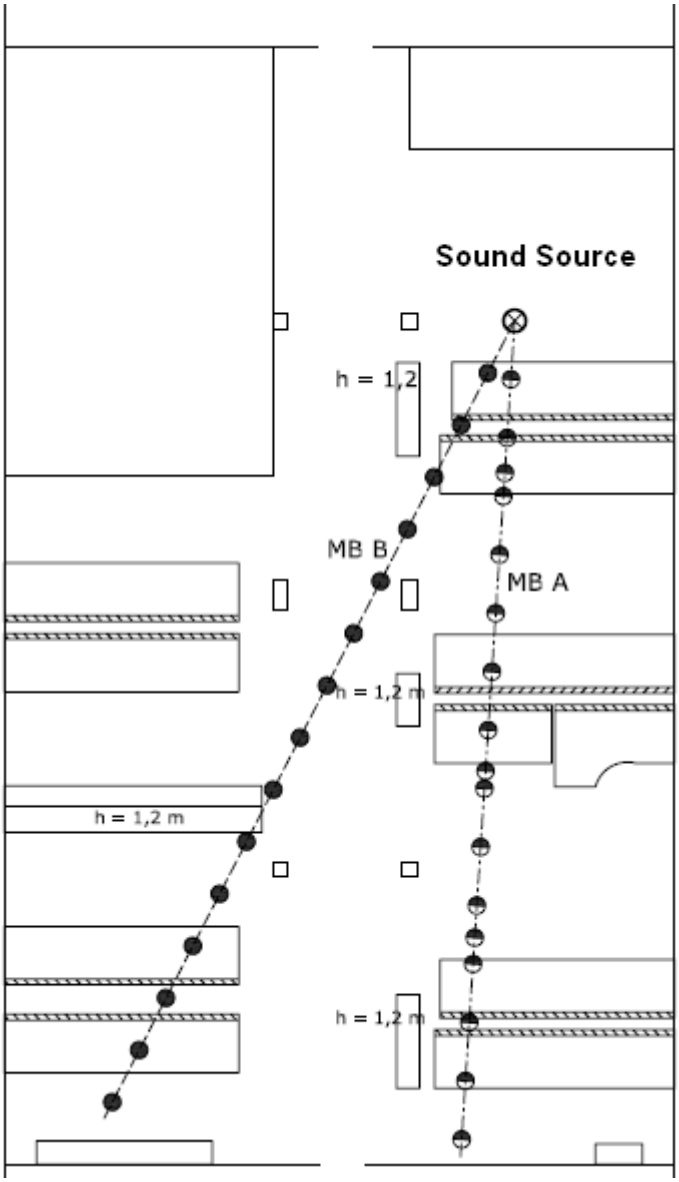

Figure 2. Measuring path for DL_2 and DL_f.

B. Inquiry

The measurements of objective room acoustic parameters were accomplished by an inquiry among the staff. The purpose of the questionnaire was to identify critical criteria with regard to the subjective impression of the working environment. Moreover, the results from the questionnaires were compared with measured room acoustic parameters. The inquiry and the room acoustic measurements were performed both before and after the refurbishment of the open-plan offices. Before implementation, the questionnaire was tested on experts on acoustics, as well as on a number of people who work in open-plan offices. The completed questionnaire comprises of sixty questions, and takes at most twenty minutes to answer.

C. Acoustic treatment

In general terms the refurbishment in the two offices consist of partly or totally new suspended ceilings corresponding to α_w>0.9. As a complement to the acoustic ceilings patches of free hanging sound absorbing units were installed over the workplaces. This is illustrated in figure 3. In one of the offices sound absorbing screens were placed between the workplaces. In both

offices, wall absorbers were mounted on one of the walls. The basic idea behind the acoustic design was to prevent speech propagation between different working teams.

Figure 3. Free hanging absorbing units above workplaces

3. RESULTS

A. Measurement of DL_2 and DL_f

Speech is the most disturbing sound signal in an open-plan office. How to increase the attenuation of speech between different working groups is consequently a question of major importance in the acoustical planning. To quantify the attenuation of sound during propagation measures like DL_2 and DL_f are appropriate. These parameters are defined in ISO 14257[7]. In this investigation A-weighted pink noise was used as a sound source. Knowing DL_2 and DL_f and specifying a target value for acceptable speech level L_c at a work place, the distance needed between the person talking and the workplace is given

$$d_c = 10^{0.3(L_{speech} + DL_f + L_c)/DL_2} \quad (1)$$

where d_c is the distance of comfort, L_{speech} is the level of speech and L_c is the acceptable speech level at the work place.

This (comfort) distance gives an indication of how to proceed in the acoustical design work concerning absorbing materials, screens, furnishing etc. and act as a useful tool for the architects.

DL_2 and DL_f have been measured along the paths illustrated in figure 2. The values constitute average for both directions and for the range 3 to 10 meters along these lines. The results before and after refurbishment are presented in table 1. As appear from table 1 the acoustical treatment has affected both DL_2 and DL_f. Since DL_2 has increased and DL_f has decreased after treatment this imply that for distances larger than 3 meter from the source, the speech level will decrease faster as a function of distance and the speech level in each position has diminished. As a consequence and according to equation 1 the distance to reach an acceptable speech level has been shortened.

Table 1: *Sound propagation measures DL_2 and DL_f before and after refurbishment*

Before refurbishment		
Office	DL_2 (dB)	DL_f (dB)
1	3.3	6.7
2	4.5	7.5

After refurbishment		
Office	DL_2 (dB)	DL_f (dB)
1	5.0	0.6
2	7.0	2.6

B. Questionnaire

The questionnaire comprises 60 questions. Most of the questions are divided into five multiple-choice questions. The number of respondents regarding the answer of the questionnaire before and after the acoustic treatment was 14, respectively 10 in office 1. In office 2 the corresponding numbers was 16, respectively 7. For the sake of clarity we will only refer to the question how the staff considers the acoustic environment from a general point of view before and after the refurbishment.

Office 1:

Before refurbishment: 60% consider the acoustic environment, from a general point of view as “bad” or “very bad” (“bad” 40%, “very bad” 20%).

After refurbishment: 10% consider the acoustic environment, from a general point of view as “bad” or “very bad” (“bad” 10%, “very bad” 0%).

Office 2:

Before refurbishment: 69% consider the acoustic environment, from a general point of view as “bad” or “very bad” (“bad” 31%, “very bad” 38%).

After refurbishment: 29% consider the acoustic environment, from a general point of view as “bad” or “very bad” (“bad” 29%, “very bad” 0%).

The evaluation of the questionnaire indicates a positive effect of the refurbishment program. However since the number of respondents is quite small the results has to be evaluated with some cautiousness.

4. CONCLUSIONS

There is a need for complementary parameters for the acoustic evaluation of open-plan offices. Ordinary room acoustic parameters like reverberation time are not sufficient for a relevant characterization of the acoustic environment in open-plan spaces. The influence of the interior design on sound propagation over distance is a crucial factor for the overall impression of the acoustic environment and its suitability as an efficient work place. Measures related to sound

propagation like DL_2 and DL_f are therefore appropriate for open-plan spaces. In two open-plan offices a refurbishment program has been performed. It has been shown that DL_2 and DL_f are sensitive for the acoustic treatments carried out and also reflect the improvement of the subjective judgment concerning the acoustic environment in general. Moreover, these measures can be converted into a (comfort) radius indicating the distance needed to achieve a certain reduction of the sound level from a sound source. This application could serve as a practical tool for the acoustical planning of open-plan offices.

ACKNOWLEDGMENTS

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