EAA ABAV NAG Euronoise 2015 Maastricht

Analysis of the Acoustic Conditions in the Student Restaurant

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Summary

This article shows a detail analysis of the acoustic conditions in a student restaurant at Faculty of Civil Engineering STU Bratislava. The main aim of the experiment is to evaluate the influence of several relevant factors such as architectural design of the interior, overall sound absorption and its position in the space and the number of customers in the room on the acoustic conditions.
First, the measurements of noise together with calibrated sound recordings were performed in the environment of the students canteen. The aim of the measurements was to find a correlation between the number of people and the overall noise levels in the room. Later, the impulse response measurements were performed in order to get the information about the reverberation time (and so the amount of the total sound absorption in the room) and the information about the general sound pressure level distribution in the room. Finally, a qualitative analysis was performed in order to confirm/reject the correlation between speech intelligibility/privacy of speech and acoustical comfort in restaurant. The acoustic assessment includes also the analysis of the changes in frequency spectrum of the measured sound under different sound level condition (caused by different number of people present) and also shows its influence on psychoacoustic parameters such as loudness, roughness, sharpness and sound fluctuation.

PACS no. 43.55.+p

1. Introduction

Noise in restaurants, as well as their soundscape assessment, are recently very discussed topics in the field of architectural acoustics [1-3]. Different acoustic features have impact on a subjective assessment of the acoustic comfort in eating establishments. Noise level together with the reverberation time values are probably the most influencing factors. Several studies have also shown an influence of sound on perceived taste of food [6].
Different theories for the description of multi-talkers environments exist, but probably the most recent are methods developed by Rindel [4] and Nijs [11].
In this article we will discuss the results of noise measurements performed in one of the student restaurants in Bratislava (Slovakia). Sound pressure levels are analysed as a function of time and number of people in the room. The difference between the days in a week is also shown. Finally, results are compared with different prediction models.

1.1. Description of student restaurant

The mentioned student's restaurant is situated at the Slovak university of technology (Faculty of civil engineering) in Bratislava.
The basic volume of the canteen is 1 775 m^3, with a floor area of 467 m^2, and a height of the ceiling h = 3,8 m. The total area of walls together with the ceiling and floor is 1443 m^2.
The floor is built out of marble tiles on concrete slab and the walls are partially plastered (in the customers area) and partially covered by ceramic tiles (in the part of food expenditure and carrying dishes). On the ceiling, there are suspended gypsum boards without perforation. The surface area of windows is around 60 m^2. The total number of tables in the canteen is 36 with a seating capacity of about 280. The total surface area of tables and seats is around 190 m^2.

The mentioned room is used for breakfast from 7:00 a.m. to 10:00 a.m. and for lunch from 11:00 a.m. to 3:00 p.m.
This article deals only with lunch-time analysis.

1.2. Description of the experiment

Experiment consisted of two parts: (1) noise measurement as a function of number of people present in a room for characterization of the users behaviour and (2) measurement of the reverberation time for characterization of the room from acoustical point of view.

1.2.1. Measurement of noise level

For noise measurements in a canteen, two condenser microphones Behringer ECM 8000, connected to the solid state recorder Tascam DR - 40 were used. Sound in the restaurant was continuously recorded during the whole lunch break (several days) and analysed in later post-processing using PC.
Calibration was performed by recording the sound signal from the piston calibrator at 94 dB (1kHz) presuming an omnidirectionality and a flat spectral response of the used microphones.

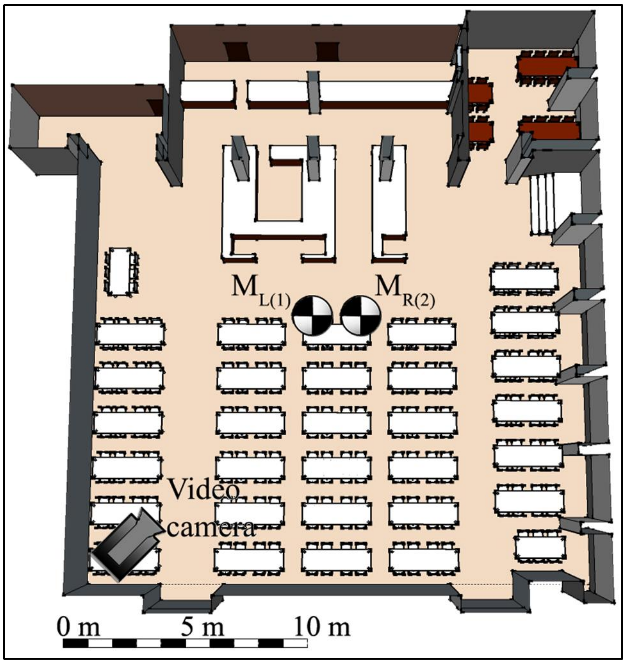

Figure 1. Position of microphones during the measurements of sound pressure level

Both microphones were placed in the middle of the room in the height of 2 m and at a distance of 23 cm from each other. The positions of microphones are shown in Figure 1 and Figure 2.

Figure 2 Photo from the canteen during the measurements

For monitoring of the number of people in the room during the noise measurements, a video camera was mounted in an upper corner of the room.
Number of people was saved every minute together with an actual value of equivalent sound pressure level.
Figure 3 give a view from camera and an idea on how the number of people present in the room was estimated.

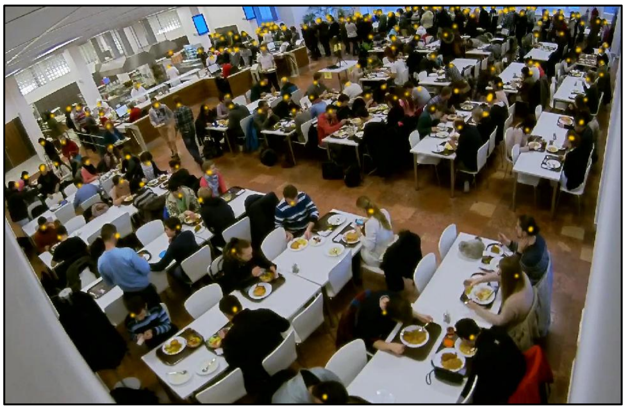

Figure 3. View from the camera (example of the measurement on 10th december 2014, minute 28, 182 people present)

1.2.2. Measurement of reverberation time

The impulse response measurements were performed by means of omni-directional sound source and condenser microphones for two positions of the sound source and 20 microphone positions using sweeps signal in the Dirac software.

1.3. Results and analyses

1.3.1. Noise levels

The typical background noise level in the empty canteen fluctuates between 45 - 47 dB and it is caused by mechanical noise coming from equipment in the room such as refrigerators etc.

The Figure 4 shows the global result of all measurements, with the general dependence of noise levels on the number of people present in the given room. It can be observed, that the increase of noise levels with the number of people in the room is steeper at lower amounts of people in the room which is logical as the level should normally (without the Lombard reflex go up with 3dB when the power is doubled).

Also a large fluctuation of noise levels in the room can be seen in situation when the number of people in the room is less then 10, expressing the situation before the opening of the canteen. Sounds present before the lunch break are mostly produced by impact sounds related to preparation of the meals and human voices of the personnel.

If we look at the measurements in the time domain, we can see a massive entry of students into the canteen when it is opened for a lunch. The general trend can be described as following: the larger the number of people in the room, the higher noise levels and the smaller fluctuations in levels can be observed.

In order to get an extra information about the acoustic situation in the students restaurant, analysis "per day in the week" was performed too (Figure 6).

Interestingly the trends in different week-days are similar. On Fridays the number of people never exceeds 150, whereas on Wednesdays the room is fully occupied with 270 people most of the time. Typical amount of people (in the same time) in a room on Mondays is between 100 - 170.

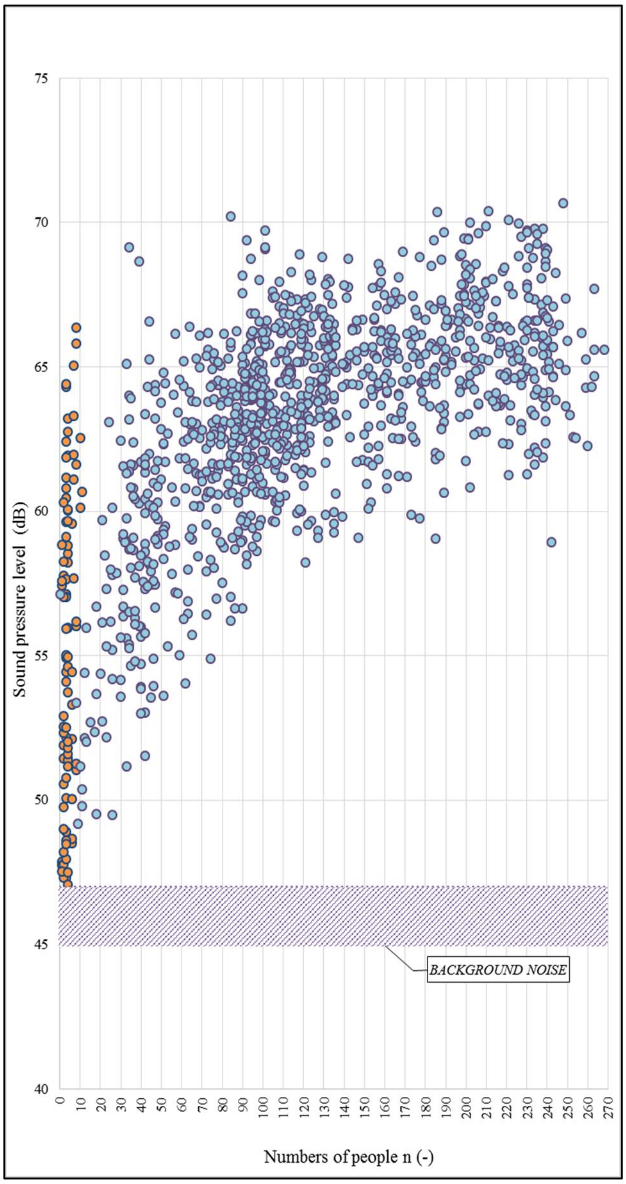

Figure 4 Equivalent A-weighed sound pressure level as a function of number of people in the restaurant

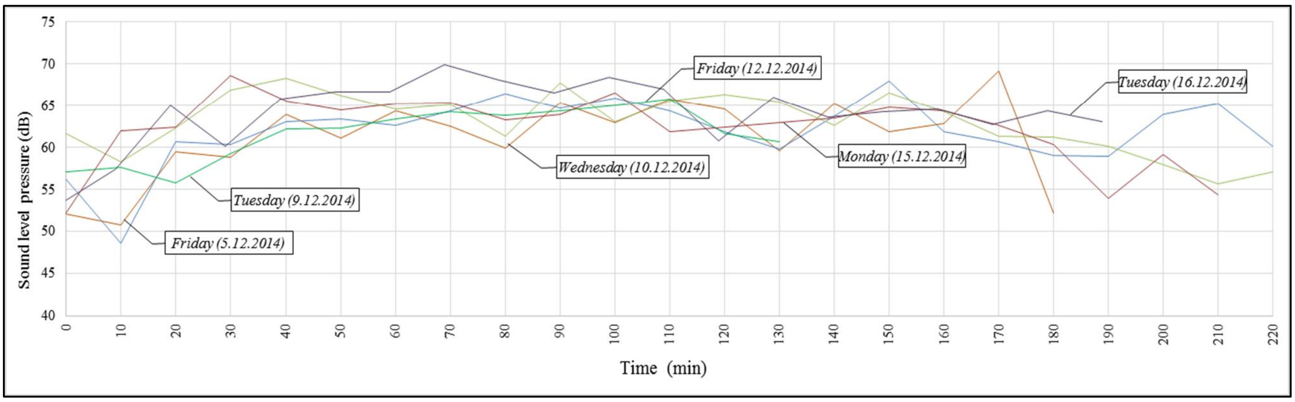

Figure 5. Sound pressure level as a function of time, given for 6 chosen measurements.

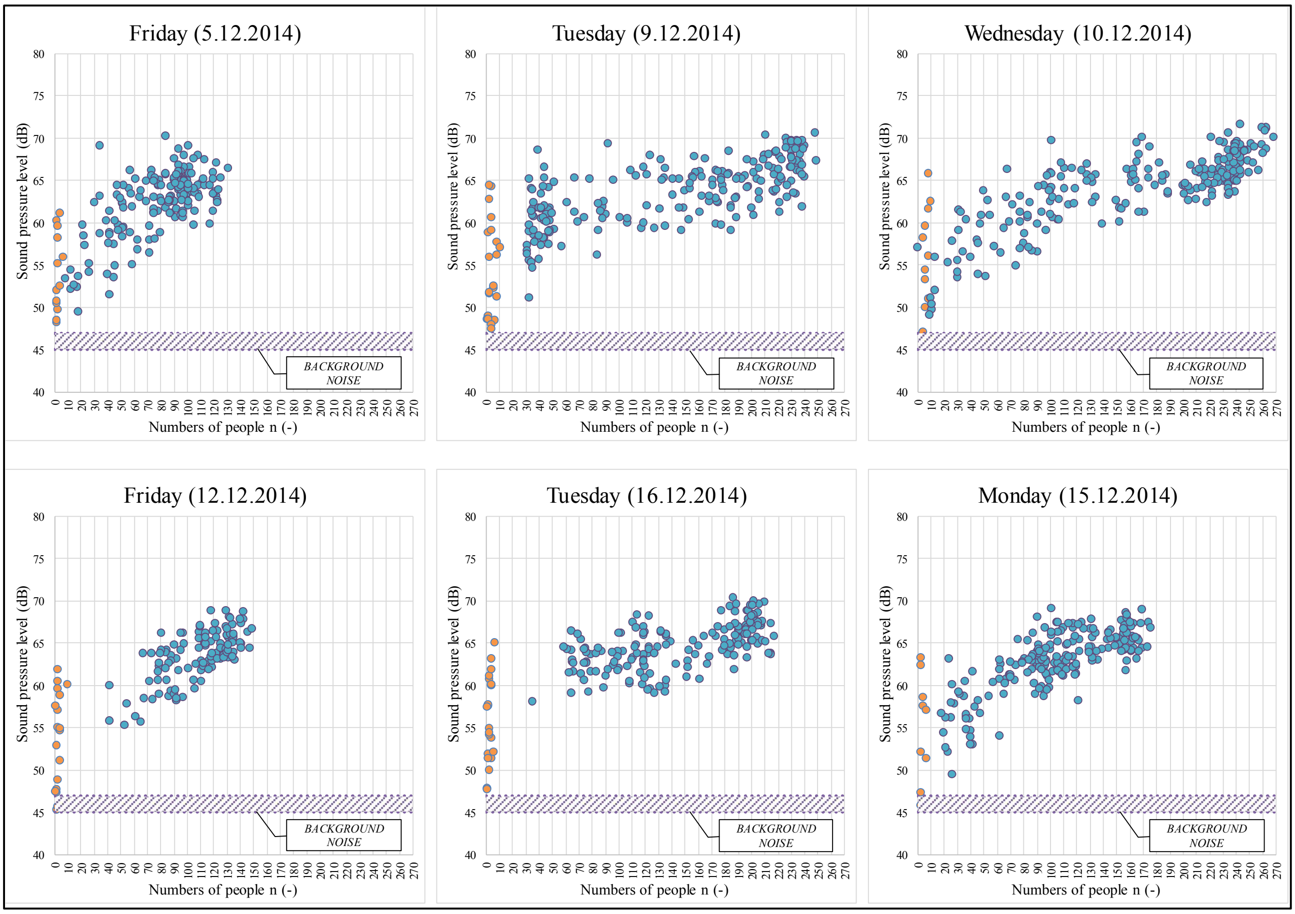

Figure 6. Equivalent A-weighed sound pressure level as a function of number of people in the restaurant analysed "per week-day". Red dots express the situation before the opening of the canteen and blue dots are the measurements performed during the lunchtime when people talk and eat

1.3.2. Reverberation time

The average values of reverberation time T_{30}, T_{10} and *EDT* are shown in Figure 7. It can be observed that the maximal values of reverberation time are in the middle frequencies.

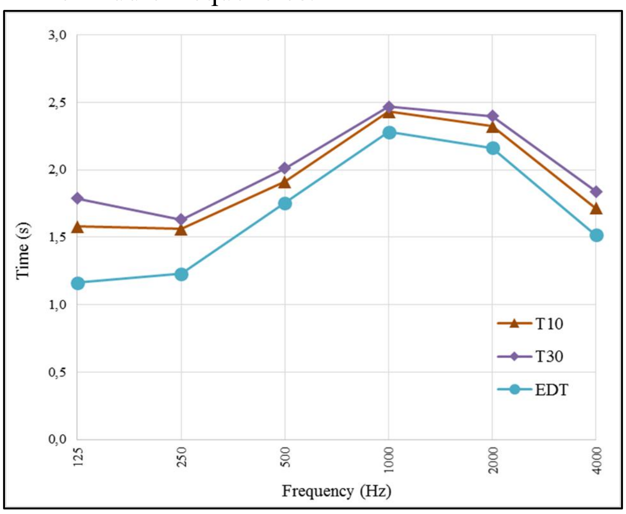

Figure 7. Average measured reverberation time T_{30}, T_{10} and *EDT* (s).

We presume, that the lowered ceiling together with sound scattering thanks to chairs and tables in the room, together with a membrane effect of large windows help to attenuate low frequencies. Hard walls and floor are responsible for reverberation time longer than 2s between 500-2000 Hz (important for speech). Average sound absorption coefficient of interior surfaces is between 0,08 - 0,12; which is too little for comfortable perception of the reverberation in this type of the room.

1.3.3. Comparison of the measurement results with a theory

The prediction model defined by Rindel [4] is in this paper used to estimate the number of people speaking in a room.

Formula defined by Rindel is given in eq. (1)

$$L_{N,A} = L_{W,A} + 10.\log(N) - 10.\log(A/4) \qquad (1)$$

where L_p (dB) is the sound pressure level, $L_{W,A}$ (dB) is the A-weighted sound power level (dB) of one person speaking, N (-) number of sound sources and A (m^2) is the equivalent absorption area of the room.

In our case study, the equivalent sound absorption area A (m^2) is between 120-180 m^2, depending on the frequency. When applying the equation (1), the sound levels between 66 – 70 dB correspond to 40–100 people speaking in the room when sound power level of one person is presumed to be $L_{w,A} = 65$dB (corresponding to sound pressure level at 1 m from the sound source $L_{p\_1m} = 54$ dB according to the ISO 9921). This means that in our case study, one on three to one on four people speak at the same time.

2. Conclusion

The noise levels in the student's restaurant are not unbearably high, thanks to a relatively high ceiling. The levels in the room are most of the time less than 70 dB, which is a value typically acceptable in a restaurant during lunchtime [11].
The mean A/N ratio is between 5-10 m^2, which is a suitable value for this type of a space.
Disturbing and tiring might be somehow higher reverberation time in the canteen. T_{30} was found longer than 2s is in all frequencies between 500-2000 Hz.
Unclearly specified acoustic discomfort in the canteen (mentioned by personnel working in the space) can be therefore explained by long reverberation of sound and can be solved only by additional sound absorption in the room.

Acknowledgements

Financial support of VEGA no.1/0358/13, VEGA no.1/0286/15 and University Science Park of STU Bratislava, Serial: ITMS 26240220084.
We would like to express our special gratitude to Zdenka Vunhuová for her permission to perform our experiments.
Sincere thanks is addressed also to Veronika Bretzová, Zuzana Lišková, Kamil Binek, Tomáš Filo and Nguyen Tien Minh and Júlia Zrneková.

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