FEEDBACK FROM THE FOODCOURT

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Restaurants can be very noisy, seriously hampering pleasant conversation. The Lombard effect describes the phenomenon that people tend to raise their voices in a noisy environment, thus increasing the noise level: feedback! As a result, especially in large, bare rooms high sound levels can occur, caused by groups of people, e.g. in restaurants. Empirical formulae show that the most important variables are the number of people, the reverberation time and the volume of the room. It appears that the most appropriate instrument to somehow control those sound levels is the amount of sound absorption in the room. The assumption has been made that the behaviour of the persons present in the room is ruled by the desire to communicate with each other. Hence simple rules for the design of the acoustical properties of the room are deduced. The acoustical properties can easily be linked with the maximum "allowable" number of patrons, and so even with the number of seats . This is demonstrated in a case study of a mid-size restaurant by adding a somewhat absorptive ceiling, and much more absorption as alternatives.

1. Introduction

It is a common experience that the noise level caused by the conversation within groups increases with the number of people; proportionally at first, when not many people are present yet, but increasingly so if certain limits (noise level or number of people) are exceeded. This is a common source of complaints for restaurants patrons[1]. This raises the question whether the sound pressure level caused by the people in a room can be predicted or estimated in some way. At least as important is the question to what extent the acoustical properties of the room determine the sound pressure levels, and can be manipulated accordingly.

The mean sound power level of a speaker in a normal environment (not too noisy) is about 65 dB(A) re 1 pW. From the number of speakers (n) in a room, and the amount of sound absorption (A [m^2]) the resulting sound pressure level in the (diffuse) reverberant field can be calculated:

(1) $$L_p = 65 + 10\,lg\left(4\frac{n}{A}\right)$$

1 An internet search with keywords *quiet restaurants* shows many complaints

The validity of this formula is limited to low ambient sound levels[2]. As stated, sound levels can become (much) higher when the number of people increases. It is a realistic assumption, that the underlying reason is the intention of people to maintain conversation. Speakers want to make themselves heard; listeners want to understand what is said. A thought experiment can be useful to get a clear picture of the mechanisms involved. A restaurant, where patrons are sitting at tables, can be compared to a cocktail party, where people are freely moving around; the comparison is stronger when more people are present, and that is the most relevant situation.

Consider a room where a gathering is held. People arrive one by one; at first forming a circle, with only one speaker at a time. The distance between neighbours in the circle will be constant, e.g. 1 m. As the number of people grows, the perimeter and consequently the diameter of the circle do, until conversation becomes less easy, because the distance between the speaker and some of the listeners hinders the speech intelligibility. At this point the circle breaks up into two smaller ones. These new circles keep growing with new participants entering, until they break up again. In this way, the number of speakers increases, and so does the sound level in the room. This causes the speakers to raise their voices. The effects of the number of patrons, trying to maintain or start their conversation, and the amount of sound absorption can be expressed in a model, based on the extensive literature on speech intelligibility, preferred speech levels, etc.

Of course communication comprises more than speech and intelligibility. Saarinen [1] points at non-verbal communication, behaviour in a wide sense, including proxemics: the use of space by individuals in a group. These aspects are not taken into account. They should be kept in mind in the interpretation of experiments, and explain a part of the variance in the results.

2. Conversation circles

As the vocal output of persons taking part in a conversation, depends on the background level, but the background level itself is largely determined by the vocal output of the speakers, the phenomena in conversation circles must be regarded as a system with feedback. Under certain assumptions, the process can be calculated by means of a quantitative model, resulting in the sound level in a room as a function of the number of persons present and the amount of sound absorption. This sound level will be called the Lombard level, after the French physician who in 1911 first described the phenomenon of speakers raising their voices when background noise levels increase.

The members of the group are supposed to take part in the conversation. Therefore they strive to understand the speech of each member of their own circle. Only one member speaks at a time. If speech intelligibility is unsatisfactory, people will leave the circle to join a smaller circle or to form a new, smaller one. Smaller circles mean shorter distaces between speaker and listener, and consequently better intelligibility. The vocal output of each speaker is dependent of the momentary sound level: the Lombard effect. When the number of people in the room increases, the number of speakers will increase, and their vocal output as well. In this way very high sound levels can develop.

This model was implemented in a number of spreadsheet programs and described in [2]. The model assumes a diffuse reverberant sound field, and behaviour of the speakers as described before. The main result is presented in Figure 1: the Lombard level (expected sound level) as a function of the amount of sound absorption per capita.

Roughly a sound level of 60 dB(A) can be regarded as the start of noisiness in restaurants, and Figure 1 shows the corresponding (minimum) amount of sound absorption per capita: A/n ≈ 5 m^2.

2 Where not stated explicitly otherwise, sound pressure level is meant

3. Examples Group Vocal Output

For a number of occasions, data regarding number of patrons, amount of sound absorption and measured equivalent sound levels were compiled; partly from literature i.c. Gardner [3], Tang et al. [4] (canteen), Navarro and Pimentel [5](food courts J and L),others from Peutz' archives (school Leyden). The data points are shown in Figure 1; they match rather well with the calculation model based on conversation circles, as introduced above.

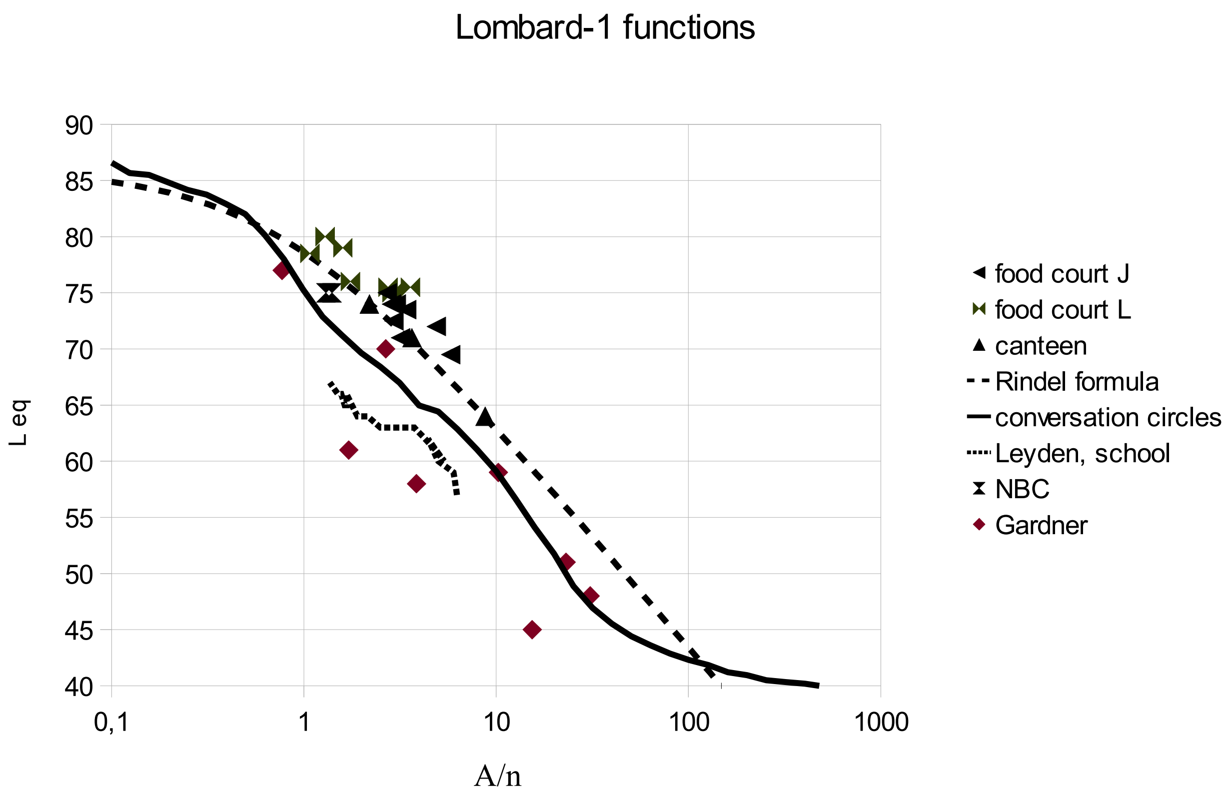

Figure 1. Equivalent sound levels in dB(A) as a function of sound absorption per capita.

Rindel [6] too started from the assumption that people want to maintain conversation, in canteens, food courts etc. He gives a predictive formula for the sound level as a function of the sound absorption per capita; it has three parameters:

- the speech level rise due to increase of ambient noise c, here c=0.5 dB/dB;
- the size of the conversation group or the number of persons per speaker g, here g= 3 persons
- the amount of sound absorption per person a, here a= 1 m^2 (clothing)

The Lombard-1 function with these parameters is shown in Figure 1 as a thin smooth curve, and fits rather well in our framework. An important difference of Rindel's approach is the percentage of speakers (=100/g): in his model it is a (chosen) parameter, in our model it is an internal variable. This might be attributed to the specific ambiance of food courts, canteens etc., where people move less freely "from circle to circle".

A similar approach is followed by Whitlock and Dodd [7]; for values of A/n >1 (absorption per capita) their results are in good accordance with Rindel's.

4. Architectural guideline

An amount of sound absorption per person of around 5 m^2 can be adopted as a general guideline for noise control. If this condition is met, one may expect that the sound levels caused by the conversations in the room will not rise to extreme values, but remain below 60-65 dB(A). Of course, no guarantee can be given: noisy behaviour is ruled out.

In restaurants the fact that a certain fraction of the patrons are eating and not talking should be taken into account. If we assume a silent fraction of 30%, the amount of sound absorption per capita reduces to 3.5 m^2.

Next we can take the step to consider the number of seats, the seating capacity. Here we may assume an an occupation of 60% of the seats. In this case the required amount of sound absorption per seat will be 2 m^2.

Usually the available space per seat in restaurants is in the range of 0.8- 2 m^2. This equals – and limits! – the available space for sound absorption in the ceiling plane. A highly sound absorbing ceiling, and some additional absorption of furniture, floor and walls may lead to an effective amount of sound absorption of 1.3 m^2 per m^2 floor area. Hence a minimum floor space per seat of 1.5 m^2 is required.

5. Reverberation time

In the preceding chapters the reverberation time was not mentioned. The reason is, that the speech intelligibility in the conversation circles is practically independent of reverberation time. The ambient noise is the limiting factor here. This is not to say that “the” reverberation time is not important at all [8]. Especially in large dining halls where public address systems are used, the reverberation times should be regarded. Musical performances and reproduction of music of course have their own sets of requirements, including reverberation time. These aspects could require a much larger amount of sound absorption than proposed in the previous chapter.

On the other hand, in low-ceilinged rooms with highly absorbing ceiling and walls the reverberation time may be very short; too short to be comfortable. Increasing the height of the room – if feasible– is a solution from an acoustical point of view. However, with the starting points from chapter 4, a target value of T= 0.8 s would require an effective height of h= 7 m if 2 m^2 floor area per seat were available.

6. Case study

6.1 Premises description

A case study is a restaurant located in the city centre of London (Figure 2). At the time of writing this paper, the restaurant was under development. It is planned to occupy a ground floor of an existing multi-storey building where all floors above are dedicated to residential flats. The new commercial unit will include a dining area, kitchen, office and other service rooms. Volume of the actual dining space will be approximately 462 m^3. It is proposed that the whole front wall will be changed into glazing with a bi-folding door to allow expanding of the dining area towards the street. The restaurant has been planned to operate with 58 seats not including the outside seating area.

In first instance the proposed by the architect finishing materials proposed by the architect, used in the interior design of the dining space were as follows:

- Walls and partitions: plasterboard
- Floor: wooden floating floor on a concrete base

- Glazing wall: double glazing of 6mm/12mm/6mm
- Ceiling: plasterboard coffered ceiling with air-conditioning units.

Figure 2. Floor plan of the restaurant.

6.2 Reverberation time in the restaurant

It is recommended that for “live” acoustic experience in restaurants and adequate speech intelligibility, reverberation time at frequencies 500-4000Hz should be about 1.0s [9] while at low frequencies (where most plant operates) and in high frequencies (generated by clattering cutlery, plates or glasses and scraping chairs) it should be shorter.

Placing absorbing material on the ceiling in the restaurant is usually the easiest way, as it is sometimes the only freely available surface in the room. However, mixing of absorptive and reflective panels on the ceiling and walls may also be considered to keep reverberation time down. Figure 3 demonstrates reverberation times in the restaurant calculated using an acoustical modelling software program.

Predictions have been made considering placing a Class D or a Class A sound absorber on the ceiling, and placing a Class A sound absorber on the ceiling and absorptive panels of Class C on some walls next to the tables. The average absorption area 500 – 2000Hz in each above situation is, respectively, 13.7m^2, 58m^2, 126.3m^2, and 154.8m^2. Resulting reverberation times are also shown in Figure 3. It can be seen that Class A ceiling and Class C wall panels profoundly reduces reverberation time.

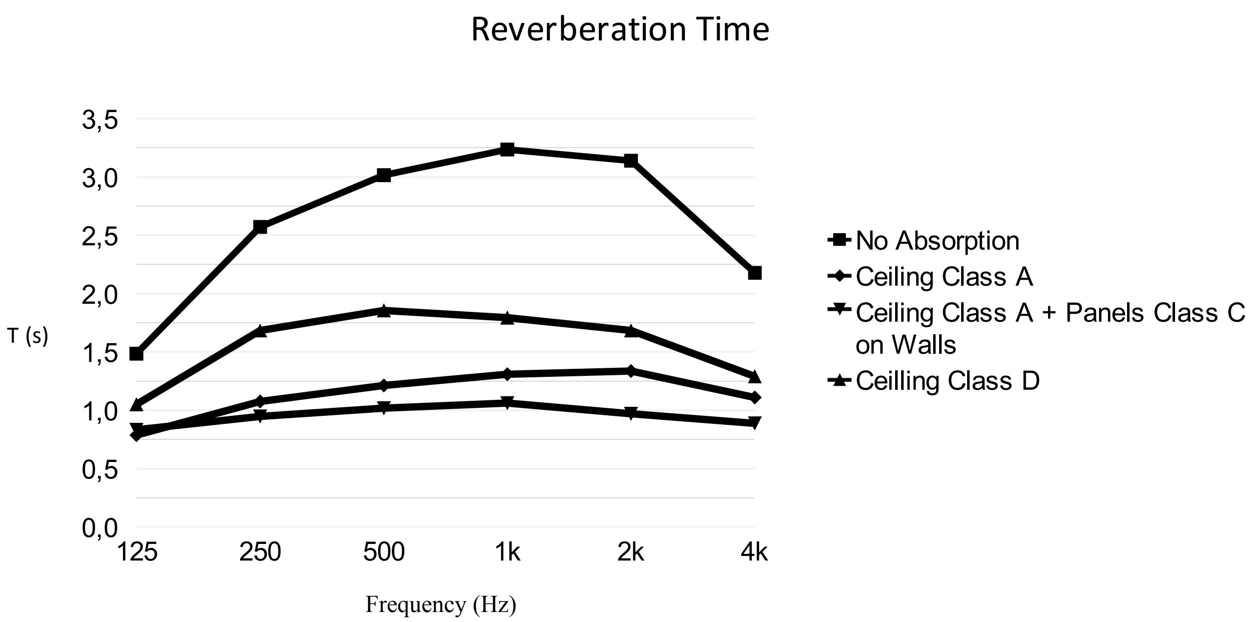

Figure 3. Calculated reverberation times.

6.3 Acoustic guidance

Calculation of the recommended maximum number of patrons in the case study considers four architectural scenarios, namely:

- Scenario 1 – no added absorption,
- Scenario 2 – with absorptive ceiling Class D,
- Scenario 3 - Class A sound absorber on the ceiling and absorptive panels of Class C on some walls next (maximum absorption).

The fourth scenario starts with a reverberation time of T=1 s. Each scenario leads to a certain amount of total sound absorption, hence to maximum numbers of patrons and seats. The outcomes of the predictions are shown in Table 1; the maximum seating capacity supposes 60% occupancy in the restaurant.

Table 1. Key data of the restaurant for various absorption scenarios.

Item	Scenario 1	Scenario 2	Scenario 3	T=1 s
Sound absorption (m^2)	14	58	155	77
Maximum number patrons	4	17	44	22
Maximum seating capacity	7	29	58[3]	38

If the numbers of patrons/seats are not exceeded, it is expected, that the sound levels caused by the patrons in the restaurant will not exceed 60-65dB(A) and thus provide adequate noise control.

Only in scenario 3 the planned seating capacity can be utilised fully.

3 Actual number of seats.

7. Conclusions

A serious amount of sound absorption is needed in restaurants, to avoid an acoustical climate where conversation is difficult. The required amount of sound absorption and the number of patrons are directly linked to each other; 3.5 m^2 per patron is a realistic value. In many cases a highly sound absorbing ceiling will be a minimum requirement.

The variables floor area, number of seats, amount of sound absorption, height and reverberation time are interconnected. For given room dimensions, the number of seats that is allowable from the viewpoint of noise control, and the resulting reverberation time can be calculated.

On the other hand, starting from a target value for the reverberation time and the number of seats, the required floor area and height are determined.

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