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ANALYTICAL MODEL TO PREDICT SPACING BETWEEN RESTAURANT TABLES IN ORDER TO ATTENUATE THE LOMBARD EFFECT

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ABSTRACT

Food establishments have the main need in the scope of acoustics to allow customers to talk at a normal voice level. Some psychoacoustic phenomena, such as the Lombard effect, can directly impact the acoustic comfort of the place. c. Among the various existing models, few deals with the minimum distance between the tables. An analytical model is proposed to calculate the minimum space between tables to attenuate the Lombard effect. The model uses as an approach the difference between the useful acoustic energy density and the disturbing acoustic energy density, linked to a value of signal-to-noise ratio. The model allows the analysis of different styles of food establishments, ranging from the calmest and most intimate to the busiest and noisiest. A comparison between analytical model results and IMMI-simulated results proved the analytical model provides consistent results. The distance between tables depends on room parameters, but in general, results can be satisfactory and practicable, especially in establishments planned to be calmer and more intimate.

Keywords: *Lombard effect, Restaurant acoustic conditioning, Space between restaurant tables, Noisy restaurant*

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1. INTRODUCTION

These days, it's fairly typical to see instances of discomfort brought on by both noise pollution and a lack of acoustic treatment for the rooms. Since loud restaurants are so popular, newspapers and magazines have started ranking the loudest ones [1].
At the turn of the century, noise has been linked to conditions including high blood pressure, ischemic heart disease, stroke, obesity, and hearing loss [2, 3, 4, 5]. Due to its association with an increase in stress, noise can also contribute to fatigue and the body's production of stress hormones [6–8].
Noise may cause economic losses as well as harm to the general public's health, particularly for the restaurant industry. Any intensity level that exceeds the "comfortable" range, according to Farber and Wang [9], can result in a loss of client satisfaction and a decline in business for the establishment.
The basic acoustic requirements for cafes and restaurants are to offer privacy and permit discussions to be held at a reasonable voice level so that background noise from adjacent tables does not interfere with your understanding. It follows that in these settings, privacy and intelligibility are crucial.
If the restaurant accommodates many groups of customers at once, the amount of background noise may rise, requiring each person to speak louder so that their tablemates can hear them. The noise level in the room rises as a result of other customers' automatic imitation of this behavior, which is known as Lombard effect [10].
Other studies [11,12] focused on the acoustical capacity of restaurants in relation to how many customers may be accommodated at once and comfortably sustain vocal conversation in the space. It's also crucial to consider that the close proximity of the tables to one another makes it

difficult and frequently uncomfortable for people to converse with one another.

Accordingly, this paper hypothesizes that, it is possible to quantify the radius of influence of the disturbing noise from neighboring tables (which depends on the degree of acoustic conditioning of the room), in order to determine the ideal minimum space between tables that is able to attenuate the Lombard effect.

2. ANALYTICAL MODEL

Prior to that, it is important to keep in mind that in a closed environment with a diffuse field, the listener is affected by sound in two different ways: directly and reverberantly. The proportionality between direct and reverberated sound depends on the distance between listener and speaker (r), the room's architecture, it means, the sum of all the room's surface (S), and the average coefficient of sound absorption of the room ($\bar{\alpha}$).

Analyzing the sound field, costumers are intercepted by two types of sound: the useful sound and the disturbing sound. The distance between tables can be predicted by a relation between the useful sound energy and the disturbing sound energy (ΔL), Eqn. (1), as well as an N factor, which depends on the restaurant style.

$$r_v = \left[\frac{10^{\frac{\Delta L+10Log(N-1)}{10}} S\alpha^{-} r^2}{S\alpha^{-} + 16\pi r^2(1-\alpha^{-}) - \pi 5^{\frac{\Delta L+10Log(N-1)}{10}} \cdot 2^{4+\frac{\Delta L+10Log(N-1)}{10}} r^2(1+\alpha^{-})}\right]^{\frac{1}{2}} \quad (1)$$

All the details of how to calculate the useful sound energy and the disturbing sound energy, as well as the N factor can be verified in Poncetti and Soares [13].

Now the question is: what ratio of useful sound and the disturbing sound should be enough to attenuate the Lombard effect?

Using the perspective of the Lombard effect, Rindel [14] investigated verbal communication and the impact of noise on the speech level in eating establishments. He evaluated the verbal communication's quality using a signal-to-noise ratio (SNR), which he defined as the level difference between a speaker's direct sound at a distance of 1 m and the background. According to his research, if SNR is equivalent to or higher than 3 dB, consumers may have good verbal communication speaking with a regular voice effort.

In order to analyze the reliability of the analytical model, results of a hypothetical case were compared to the results through simulation using the IMMI software (24 different possibilities). A t-test showed that there is no difference between the results of the analytical model and the simulation results (p=0.824).

3. CONCLUSION

The suggested analytical model produces good predictions that are somewhat consistent, depending on the room's architecture. Also, the outcomes of the hypothetical case study were nearly identical to the results of the IMMI simulation, demonstrating how accurately the model is.

The analytical model's primary function is to act as an easy tool to assist architects in making decisions on their projects regarding the spacing between tables from an acoustic perspective. The project parameters will determine how practicable these numbers are.

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