PREDICTION OF SPEECH TRANSMISSION INDEX IN EATING ESTABLISHMENTS

Musarrat Nahid and Murray Hodgson

School of Environmental Health, University of British Columbia, 2206 East Mall, Vancouver, BC, V6T 1Z3, Canada

1. INTRODUCTION

Eating establishments (EE: restaurants, cafes etc.) can produce noisy environments which can be an impediment to a comfortable conversation between customers [1]. As the noise level increases, talkers increase their voice levels in order to be heard over this noise—this is the Lombard effect [2]. This phenomenon can further increase the total noise level in an EE. Few studies have focused on controlling the noise level in eating establishments. None of those except one [3] has considered the Lombard effect, but that study didn't explore control measures to a considerable extent. The objective here is to model existing eating establishments (EEs) in the CATT Acoustics software and then, taking into account the Lombard effect, predict the acoustical conditions for speech (i.e., speech transmission index (STI) and, therefore, speech intelligibility (SI) and speech privacy (SP) in EEs without and with sound-control measures and, therefore, to determine how to design the EE to optimize the acoustical conditions.

2. METHOD

The primary talker (PT) and primary listener (PL) indicate the pair of customers between whom we want good SI. Other talkers/listeners are called secondary talkers (ST) and listeners (SL). The primary talker and the primary listener sit around a table facing each other so that the primary listener is in the direct field of PT.

The EE Voice Level Model [2] was used to take into account the Lombard effect, as CATT cannot do it automatically. It is hypothesized here that, according to this model [2], the Lombard effect occurs such that the voice output level $L_{pff1,n}$ varies with the background noise level L_n as follows:

$$L_{pff1,n} = L_{pff1,q} + asym/\{1 + \exp[(xmid - L)/scale]\} \text{ dBA}$$

in which *asym*, *xmid* and *scale* are Lombard-effect parameters, assumed unknown *a priori*, as is $L_{pff1,q}$ which is the voice level in the absence of noise. This model assumes that the room sound field is diffuse; however, a reverberant-field correction factor is used to correct for non-diffuseness of the sound field [2].

First, the talker voice level $L_{pff1,n}$ is predicted using the EE Voice Level Model. This value is put in CATT to model talkers (the sound source in CATT). Second, the SPLs at the primary listener (PL) due to secondary talkers are predicted by CATT to calculate the total noise level at PL. Finally, STI is predicted at PL (for SI) and SL (for SP). This is done by inputting noise levels calculated as the decibel sum of BNL (the noise level due to kitchen equipment, or music) and the total secondary-talker speech levels from Step 2.

In each EE configuration, predictions are done for different occupancies, namely low (LO) and high (HO) occupancies. The following configurations were evaluated: R (untreated configuration), PTC (PT seating at the corner of the room), STSS (STs are far away from PT), DV (volume is decreased by lowering the ceiling), IA-ceiling (increasing the absorption of the ceiling by applying a suspended acoustical-tile ceiling), IA-all surfaces (floor, ceiling, walls are made highly absorptive by applying thick carpet, suspended acoustical-tile ceiling, 15% perforated metal on 30 mm thick porous material), AB-2 (putting barriers around all tables, height of the barriers is 2 m, both sides of the barriers are made highly absorptive by applying wood-wool slab), AB-1 (same as AB-2 but the height of the barriers is now 1 m), RB-2 (same as AB-2 but the both sides of the barriers are highly reflective: glass, 6 mm), RB-1 (same as RB-2 but the height of the barriers is now 1 m). IA-DV (combining DV and IA-all surfaces), IA-AB-2 (combining IA-all surfaces and AB-2), DV-AB-2 (combining DV and AB-2), IA-DV-AB-2 (combining IA-all surfaces, DV and AB-2). The predictions were done in three EEs (Table 1) of different sizes.

Table1: Physical and acoustical characteristics of EEs.

EE name	Dimensions (m)	Customer density [#/floor area (m^2)]	α_{avg} [1]	N_t [2]		BNL (dBA)
				LO	HO	
MM	L_{avg}=14 W_{avg}=8.5 H=5	0.36	0.17	6	12	60.0
SS	L=12 W=5 H=4	0.75	0.16	5	10	57.4
LL	L=18 W=18 H=3.5	0.33	0.15	12	24	49.1

[1] Averaged over all octave-band frequencies (125-4k Hz)
[2] Number of talkers

CATT assigned the following quality ratings for STI: "Bad" (STI < 0.30), "Poor" (0.30<=STI<0.45), "Fair" (0.45 <=STI <0.60), "Good" (0.60<=STI<0.75), "Excellent" (0.75<=STI). Only those design-factor changes which resulted in 'fair' STI between the PT and PL in MM, both at LO and HO conditions, were incorporated in SS. Based on the results of these two types of model, a further attempt was made to obtain 'fair' STI in LL: it was divided in four compartments by using highly absorptive barriers rising up to ceiling ("Subdiv").

3. RESULTS AND DISCUSSION

Table 2: Predicted acoustical values at MM.

Case	Occu-pancy	STI at PL (for SI)	STI at SLs (for SP)
R	LO	0.39 (poor)	0.06-0.28
	HO	0.36 (poor)	0.04-0.25
PTC	LO	0.41 (poor)	0.05-0.33
	HO	0.44 (poor)	0.05-0.35
STSS	LO	0.42 (poor)	0.09-0.30
	HO	0.39 (poor)	0.05-0.27
DV	LO	0.40 (poor)	0.08-0.2
	HO	0.32 (poor)	0.01-0.21
IA-only ceiling	LO	0.36 (poor)	0.05-028
	HO	0.31 (poor)	0.02-0.23
IA-all surfaces	LO	0.40 (poor)	0-0.27
	HO	0.38 (poor)	0-0.25
AB-2	LO	0.50 (fair)	0.01-0.24
	HO	0.57 (fair)	0.01-0.29
AB-1	LO	0.48 (fair)	0.02-0.22
	HO	0.49 (fair)	0.01-0.22
RB-2	LO	0.49 (fair)	0.03-0.32
	HO	0.52 (fair)	0.04-0.36
RB-1	LO	0.42 (fair)	0.02-0.26
	HO	0.47 (fair)	0.01-0.3
IA-DV	LO	0.39 (poor)	0-0.26
	HO	0.37 (poor)	0-0.24
IA-AB-2	LO	0.48 (fair)	0-0.16
	HO	0.51 (fair)	0-0.15
DV-AB-2	LO	0.47 (fair)	0-0.21
	HO	0.49 (fair)	0-0.22
IA-DV-AB-2	LO	0.54 (fair)	0-0.21
	HO	0.50 (fair)	0-0.15

Table 3: Predicted acoustical values at SS.

Case	Occu-pancy	STI at PL (for SI)	STI at SLs (for SP)
R	LO	0.43 (poor)	0.16-0.26
	HO	0.36 (poor)	0.08-0.18
AB-2	LO	0.53 (fair)	0.02-0.22
	HO	0.55 (fair)	0-0.23
IA-AB-2	LO	0.54 (fair)	0-0.13
	HO	0.6 (fair)	0-0.18

Table 4: Predicted acoustical values at LL.

Case	Occu-pancy	STI at PL (for SI)	STI at SLs (for SP)
R	LO	0.45 (fair)	0.03-0.20
	HO	0.37 (poor)	0-0.11
Subdiv	LO	0.57 (fair)	0-0.26
	HO	0.53 (fair)	0-0.23

It seems that putting high and absorptive barriers (AB-2) around all tables of EEs may provide 'fair' STI in MM. Increasing the absorption of the room surfaces along with those barriers (IA-AB-2) may provide even better results, with the added benefit of a decreased noise level at PL compared to other configurations. These findings were also true for SS. Prediction results for the "Subdiv" configuration in LL also support these findings. Lowering the ceiling and using absorptive barriers together (DV-AB-2), or combining those two with increased absorption of the room surfaces (IA-DV-AB-2), provided good results in MM but the improvement was not significantly greater compared to IA-AB-2. Moreover, DV-AB-2 resulted in higher noise levels at PL than IA-AB-2 and IA-DV-AB-2 produced the same level of noise at PL as IA-AB-2.

REFERENCES

1. Christie, L. H. (2004). Psycho-to-building acoustics: are bars, cafes and restaurants acceptable acoustic environments? Research Report, Victoria University of Wellington.
2. Hodgson, M., Steininger, G., Razavi, Z. (April 2007). Measurement and prediction of speech and noise levels and the Lombard effect in eating establishments. *J. Acoust. Soc. Am.*, Vol. 121 (4).
3. Astolfi, A., Filippi, M. (2003). Good acoustical quality in restaurants: a comparison between speech intelligibility and privacy. *Proc. EuroNoise*, Naples, Italy, S102.