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Room Acoustics Software

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Acoustical capacity as a means of noise control in eating establishments

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Outline

- Noise problems in restaurants
- The Lombard effect
- A simplified prediction model
- Verification examples
- Quality of verbal communication
- Acoustical capacity
- Recommendations
- Conclusion

Noise problems in restaurants

- When many people are talking at the same time in a social gathering, typically in a reverberant room, it is a common experience that it can be very noisy
- Restaurants and canteens are typical examples of rooms where noise from speech can be a problem
- The sound power emitted from speech is a complicated function of the ambient noise level and social parameters

Description of speech levels

Equivalent Sound Levels of the Speaker (L_{SAm}) at a Distance of 1 m from the Speaker's Mouth for Indicated Vocal Efforts

Vocal effort		*Speech level* $L_{SAm,1m}$(dB)
Whispering		36
Soft	Speaking	42
Relaxed (p)	Speaking	48
Relaxed, normal (p)	Speaking	54
Normal, raised (p)	Speaking	60
Raised	Speaking	66
Loud	Speaking	72
Very loud	Speaking	78
Shouting		84
Maximal shout		90
Maximal shout (in individual cases)		96

p, In private quarters.

(Lazarus, 1986)

Description of speech levels

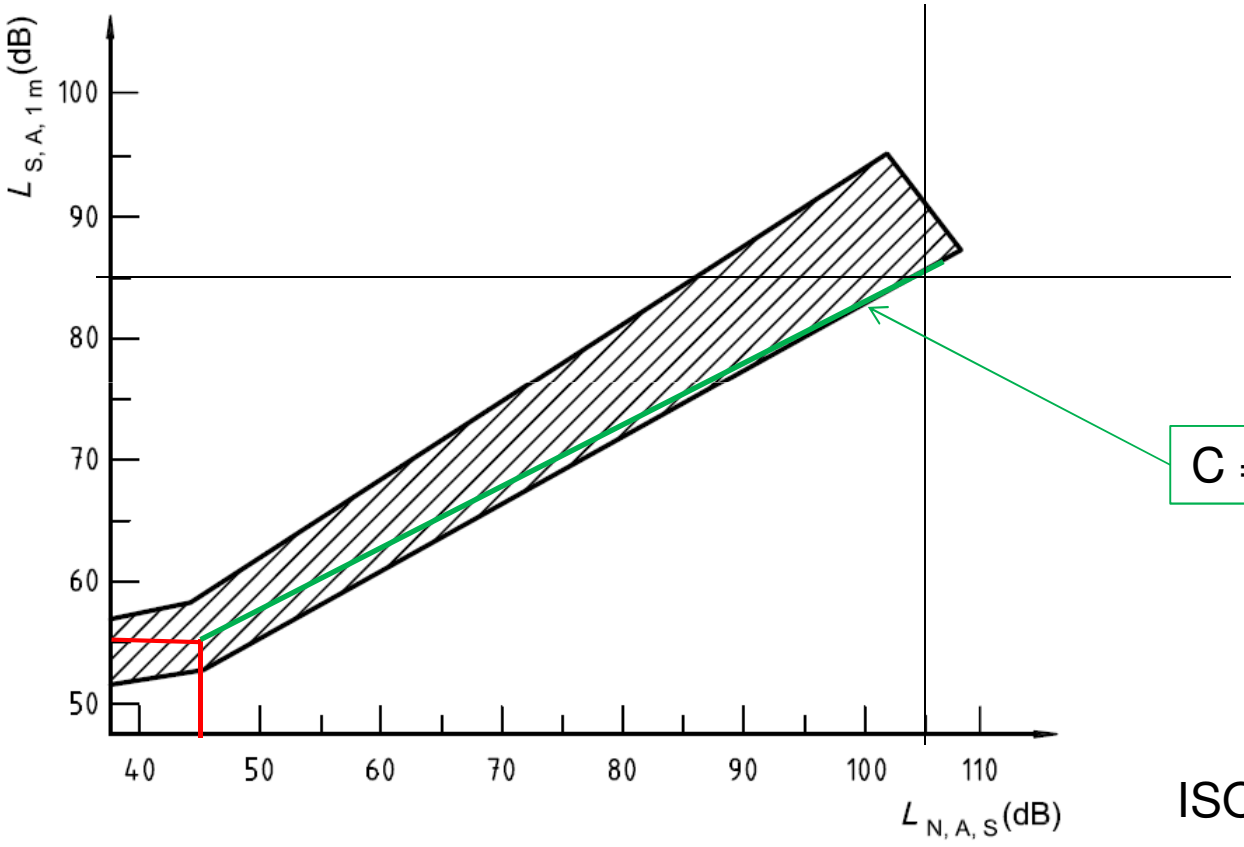
Speech level, 1m, dB(A)	Vocal effort
54	Relaxed
60	Normal
66	Raised
72	Loud
78	Very loud

ISO 9921:2003

The Lombard effect

- People adjust the speech level according to the ambient noise level (found by Lombard 1911)
- The effect can be quantified by the Lombard slope *c*
  - the speech level rise due to increased ambient noise
- Values of *c* in the range 0.5 – 0.7 dB/dB have been suggested in the literature
  - *c* = 0.5 dB/dB was found in recent study (Rindel 2010)

Effect of ambient noise on vocal effort



C = 0.5 dB/dB

ISO 9921:2003

- Relation between the range of vocal effort (equivalent continuous speech sound level) and the ambient-noise level at the speaker's position

A simplified prediction model

The Lombard effect starts at an A-weighted ambient noise level of 45 dB and a speech level of 55 dB

$$L_{SA} = 55 + c \cdot (L_{NA} - 45), \quad (\text{dB})$$

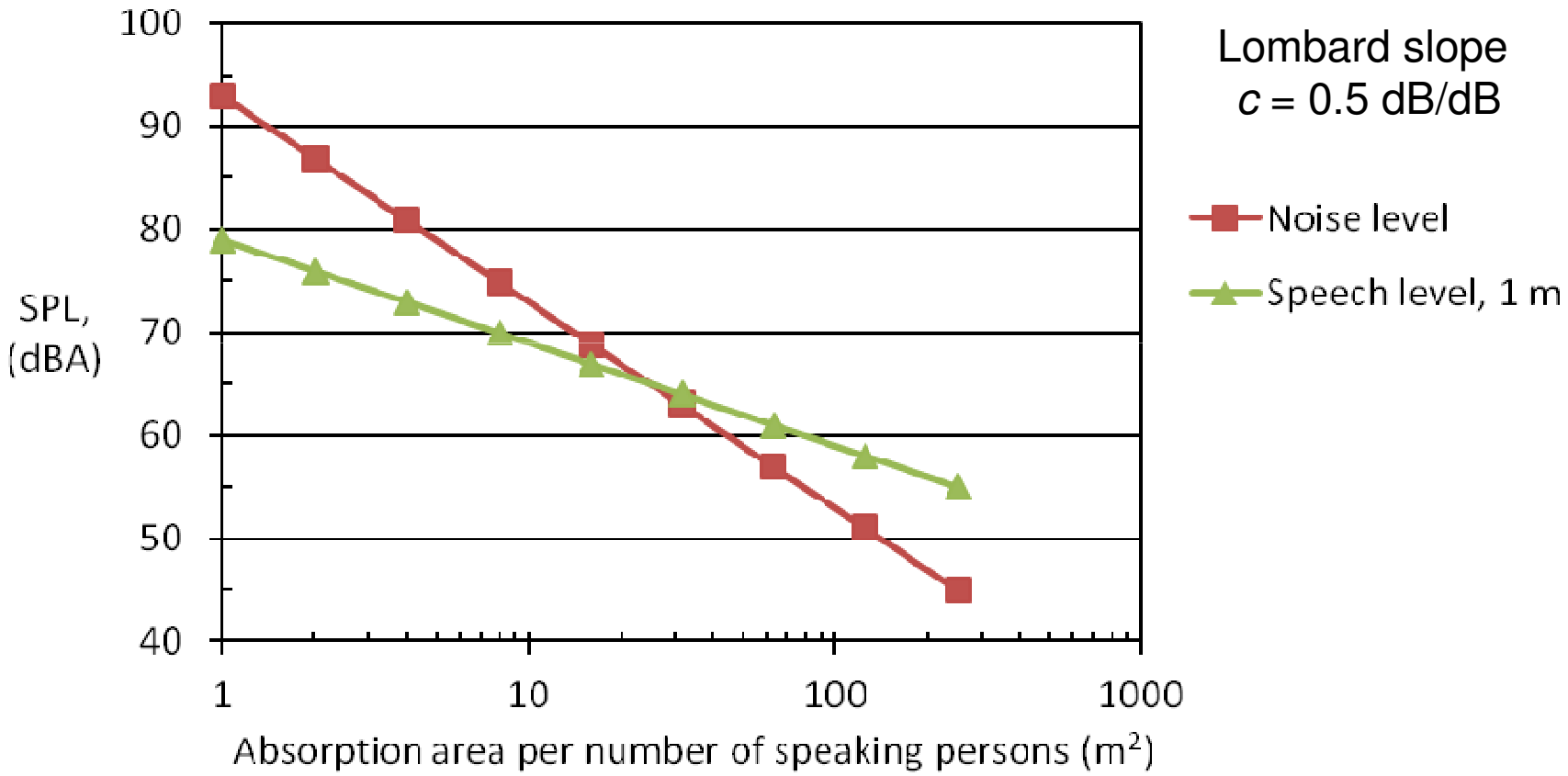
The Lombard slope is found to be c = 0.5 dB/dB.
The ambient noise level is predicted by:

$$L_{NA} = 93 - 20\log\left(\frac{A}{N_S}\right) = 93 - 20\log\left(\frac{A \cdot g}{N}\right), \quad (\text{dB})$$

A : Equivalent absorption area in the room
N_S : Average number of speaking persons
K : Number of persons
g : Group size

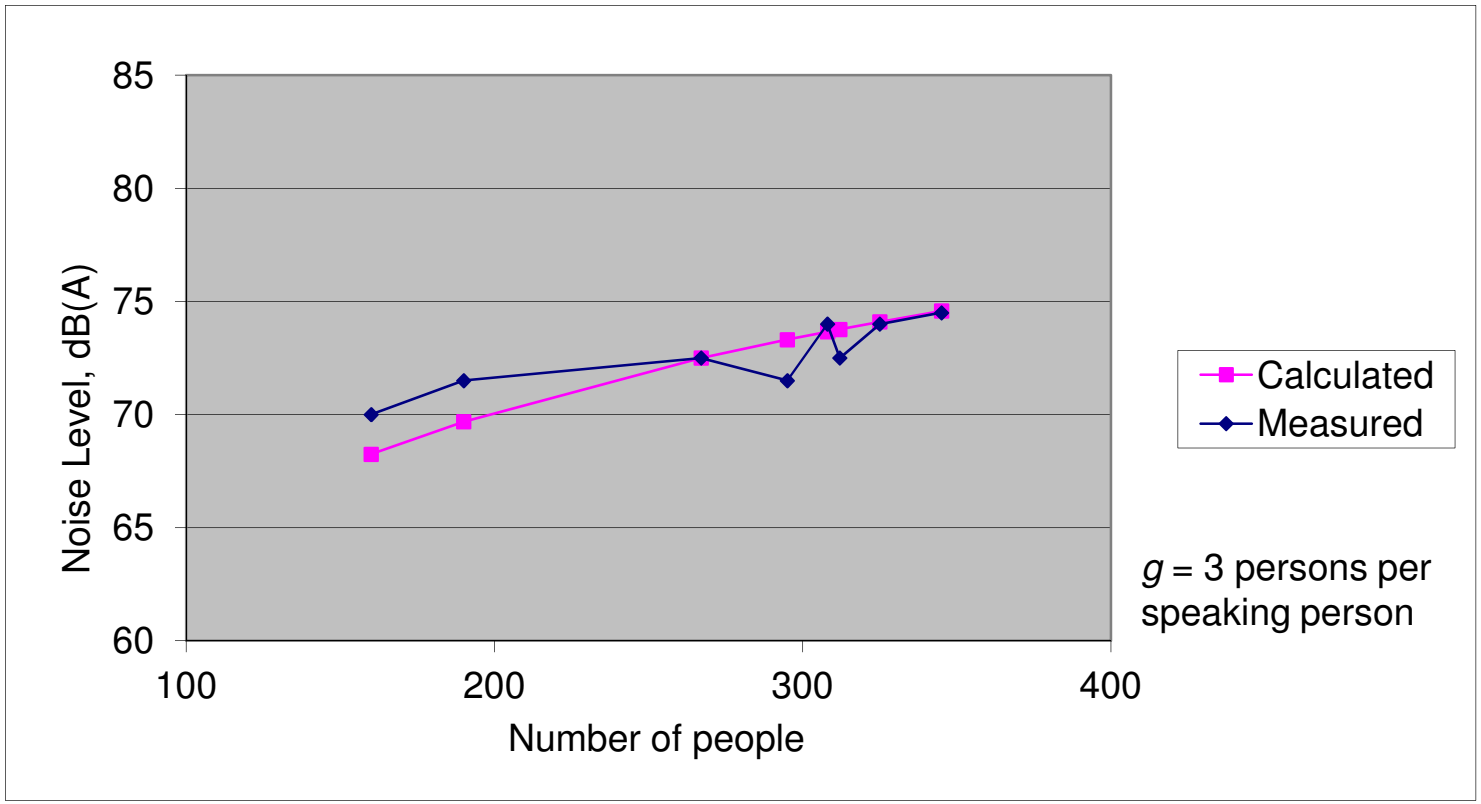
(Rindel 2010, Applied Acoustics 71)

Noise level and speech level



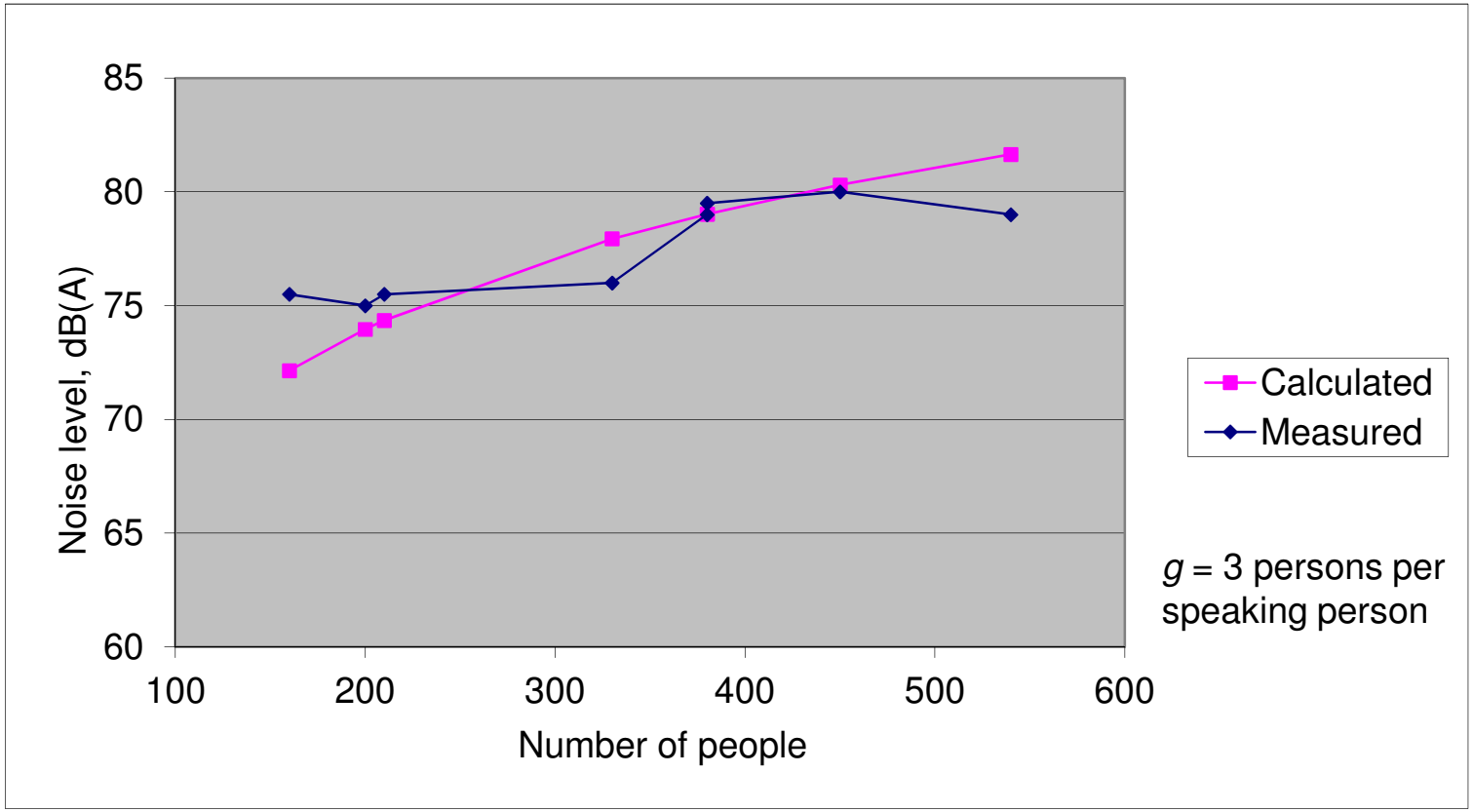
(Rindel 2010, Applied Acoustics 71)

Ex. 1. Food court, 7228 m^3, T = 1,3 s



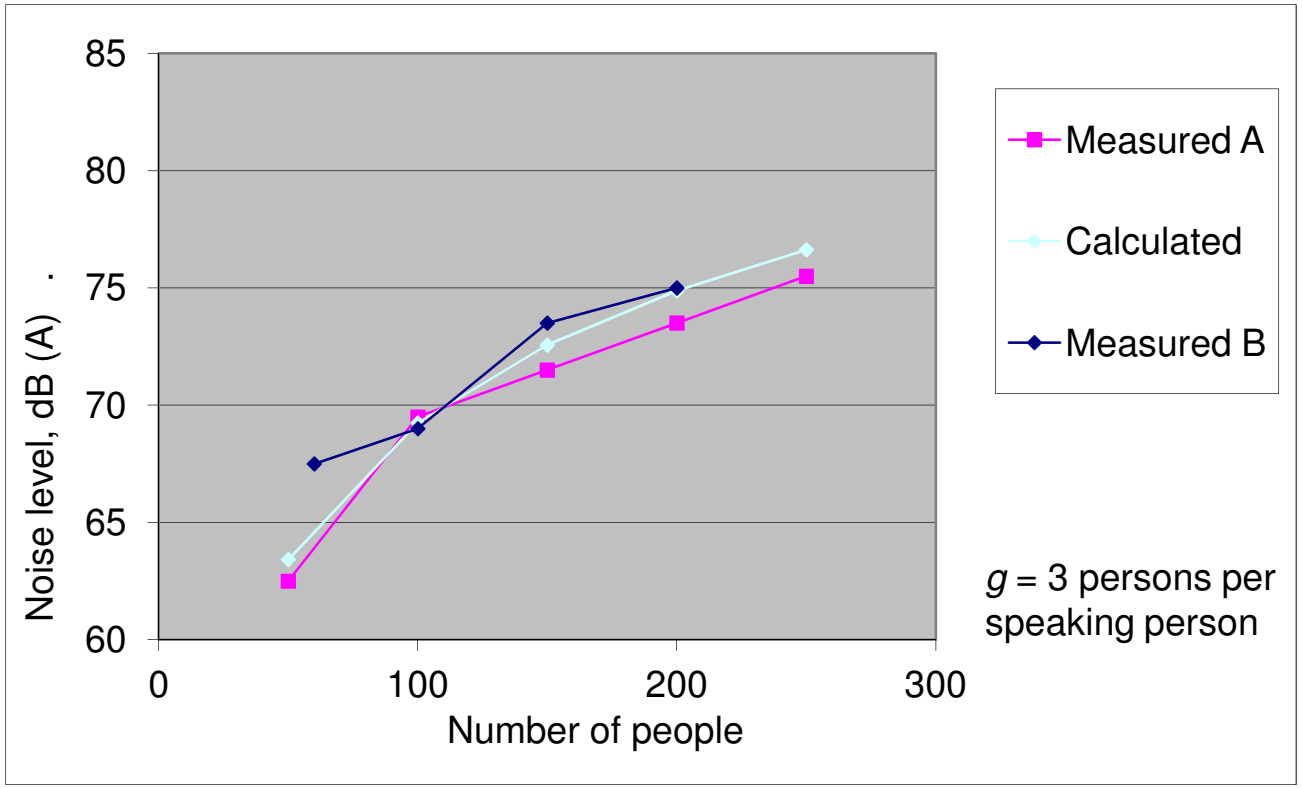
Ref.: Navarro & Pimentel (2007), Applied Acoustics 68, pp. 364-375

Ex. 2: Food court, 3133 m^3, T = 0,9 s



Ref.: Navarro & Pimentel (2007), Applied Acoustics 68, pp. 364-375

Ex. 3. Canteen, 1235 m^3, T = 0,47 s



Measurement A:
First half of lunch
Measurement B:
Second half of lunch

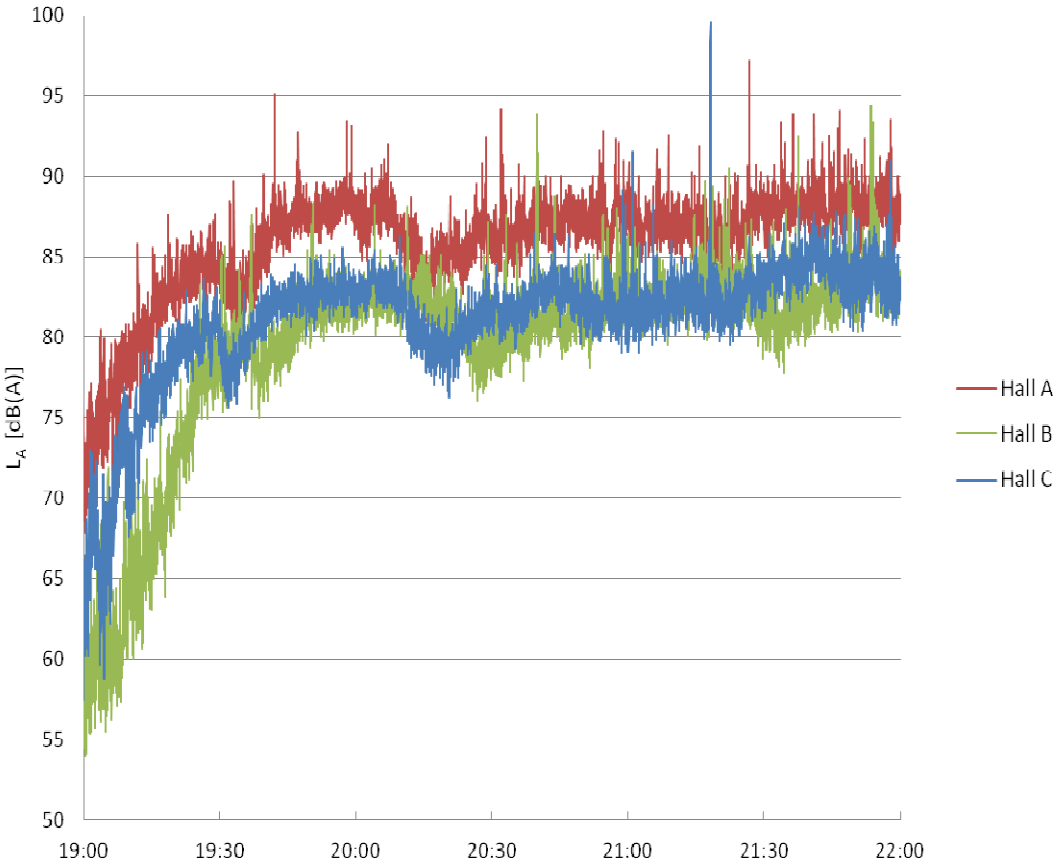
Ref.: Tang et al. (1997), JASA 101, pp. 2990-2993

Ten eating establishments

EE	Volume	RT unocc.	No. of seats	Measured $L_{N,A}$	Lombard slope	A_p	Abs. Area	Optimised Group size	Assumed Group size	Calculated $L_{N,A}$	Deviation
	m^3	s		dB	c	m^2	m^2	g	g	dB	dB
C1	619	0.5	120	75	0.5	0.5	258	3.5	4	**74.3**	-0.7
C2	412	1.0	100	76	0.5	0.5	116	6	4	**79.7**	3.7
B1	692	1.5	72	77	0.5	0.5	110	4	4	**77.3**	0.3
B2	384	1.2	46	76	0.5	0.5	74	4.5	4	**76.8**	0.8
B3	333	0.9	70	82	0.5	0.5	94	2.5	4	**78.4**	-3.6
R1	176	0.9	40	79	0.5	0.5	51	4	4	**78.8**	-0.2
R2	180	0.5	54	76	0.5	0.5	85	4.5	4	**77.1**	1.1
R3	960	0.8	126	75	0.5	0.5	255	4	4	**74.8**	-0.2
S1	297	0.5	56	67	0.5	0.5	123	9	8	**68.1**	1.1
S2	1176	0.8	106	66	0.5	0.5	288	8	8	**66.3**	0.3

Ref.: Hodgson et al. (2007), JASA 121, pp. 2023-2033

Three dining halls at DTU



Three dining halls at DTU

Room	Volume	RT	No. of seats	Measured L_{Aeq}, 19:30 - 22:00	Calculated $L_{N,A}$, (g = 3.5)
	m^3	s		dB(A)	dB(A)
Hall A	2485 *	2,5	480	87	88
Hall B	2495 *	0,8	530	82	81
Hall C	1605	1,0	380	83	83

*) Estimated volume

Ref.: Gade (2011)

Quality of verbal communication

Quality of verbal communication	SNR dB	$L_{S,A,1m}$ dBA	L_{NA} dBA	A/N m^2
Very good				
	9	56	47	(50 - 65)
Good				
	3	62	59	(12 - 16)
Satisfactory				
	0	65	65	(6 - 8)
Sufficient				
	-3	68	71	(3 - 4)
Insufficient				
	-9	74	83	(0.3 - 0.6)
Very bad				

Signal-to-noise ratio: $$SNR = L_{S,A,1m} - L_{N,A} = -14 + 10\log\left(\frac{A \cdot g}{N}\right), \ (\mathrm{dB})$$

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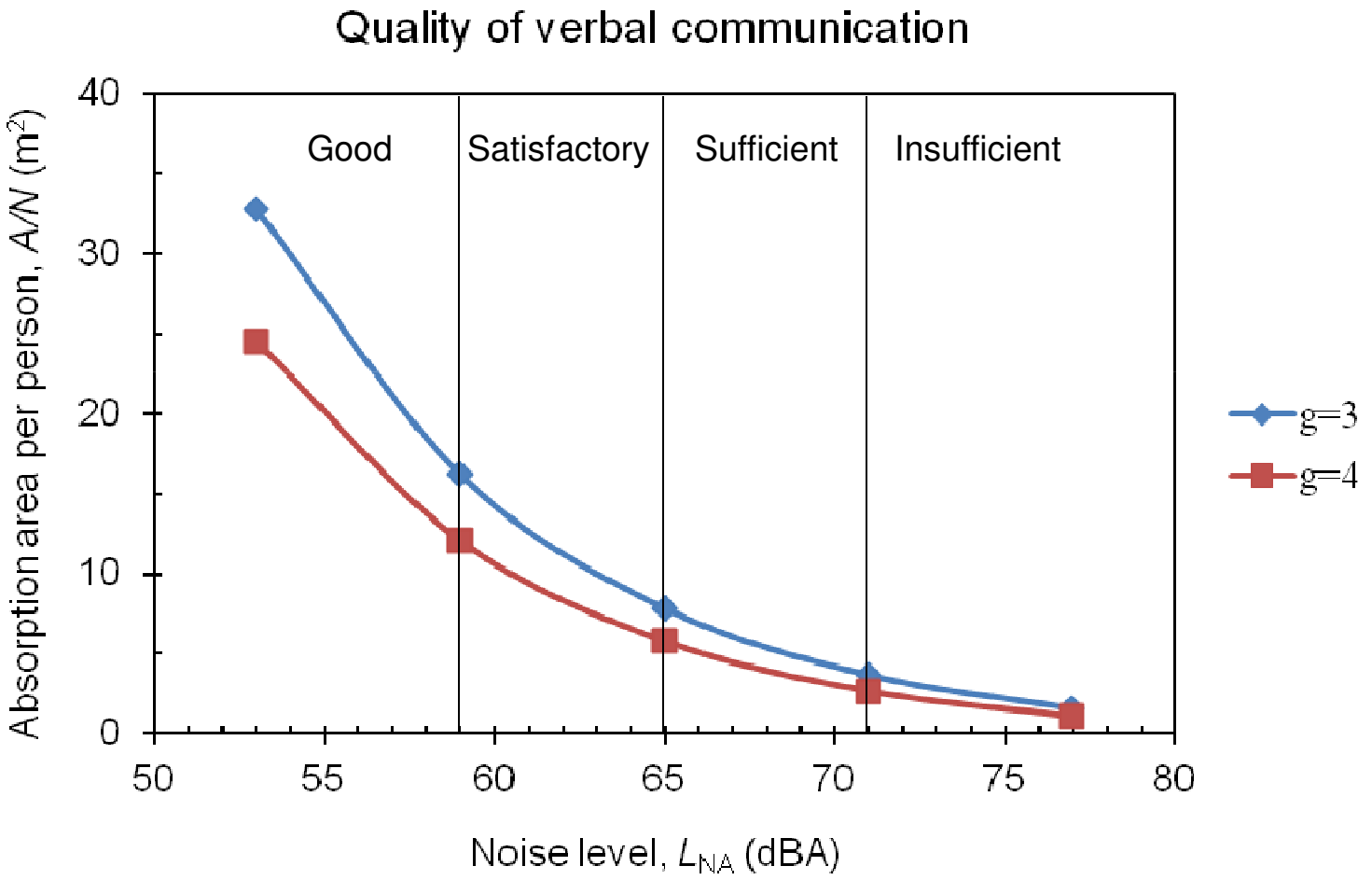
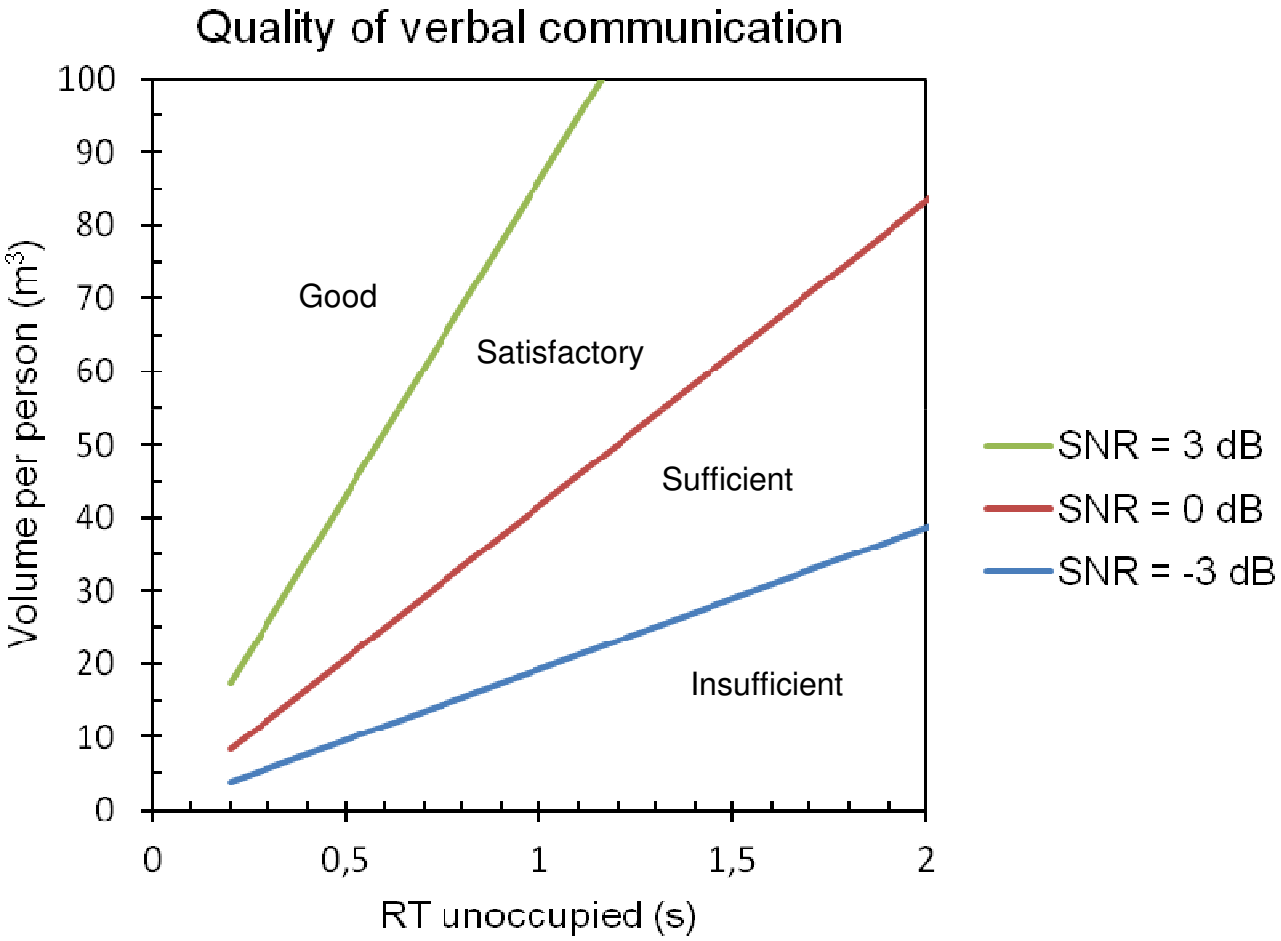
Needed absorption area per person



Needed volume per person



Acoustical capacity for eating establishments

- **Definition:** *Maximum number of persons in the room for "Sufficient" quality of verbal communication*
- Equivalent to
  - SNR ≥ -3 dB or
  - ambient noise level $L_{NA} \leq 71$ dB
- Acoustical capacity for a room

$$N(\max) = \frac{V}{20 \cdot T}$$

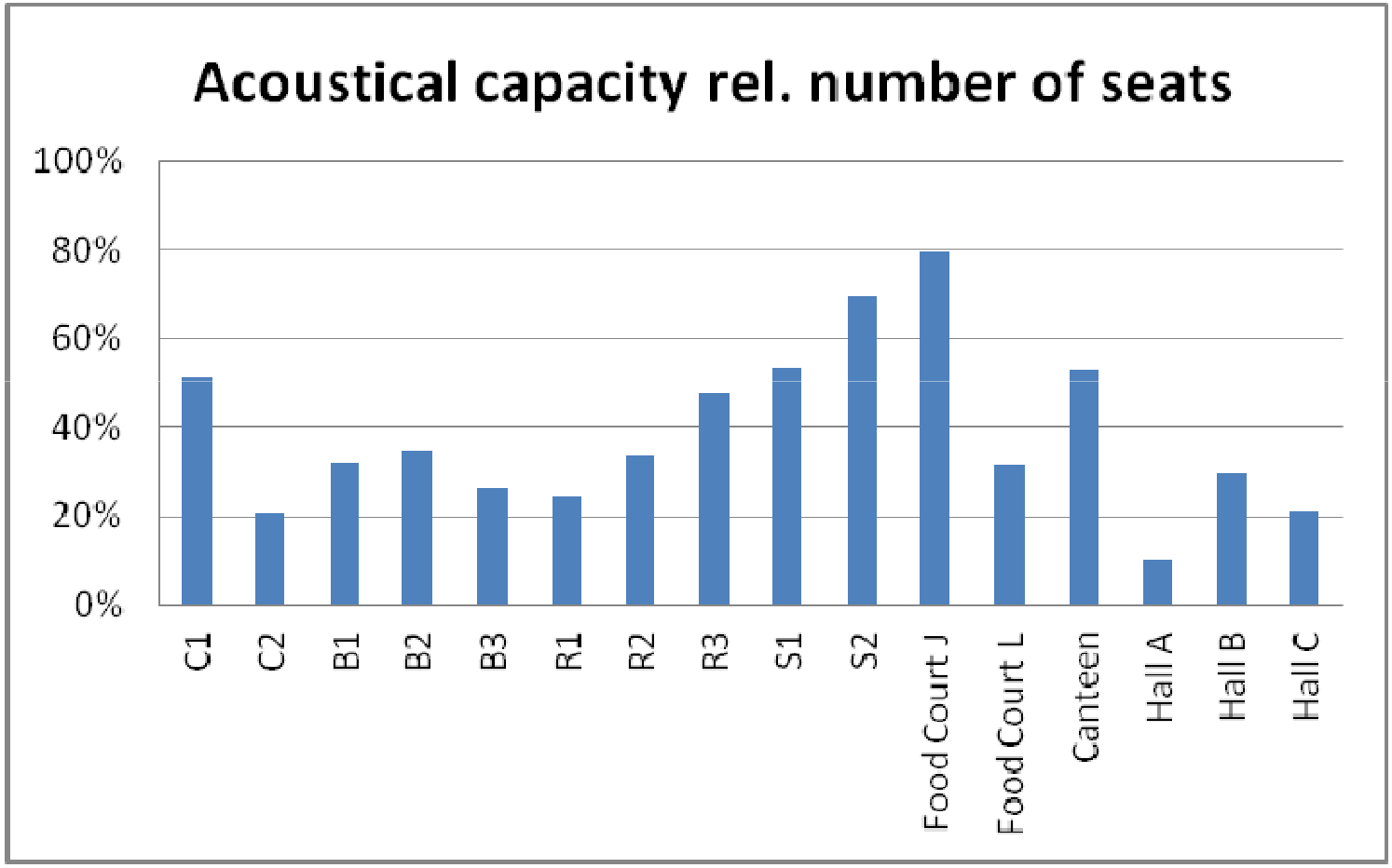
V in m^3 and T in s

- Assumptions
  - Distance of verbal communication = 1 m
  - Average group size $g = 3.5$
  - Absorption per person $A_p = 0.5$ m^2 (not significant)

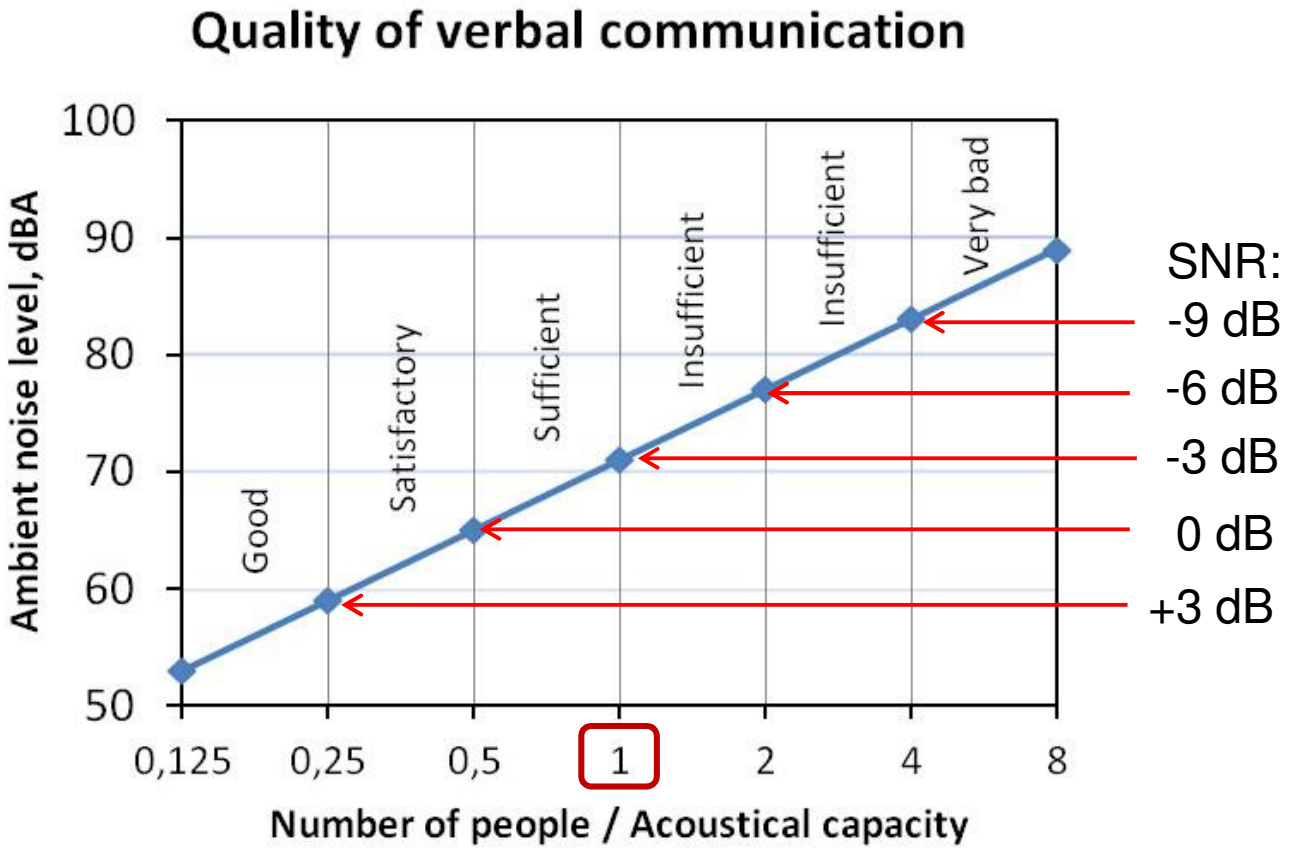
16 eating establishments

Eating Establishment	Volume m^3	RT unocc. s	No. of seats N	Ac. Capacity AC	Ratio N / AC	Ratio AC / N
C1	619	0,5	120	62	1,9	52%
C2	412	1,0	100	21	4,9	21%
B1	692	1,5	72	23	3,1	32%
B2	384	1,2	46	16	2,9	35%
B3	333	0,9	70	19	3,8	26%
R1	176	0,9	40	10	4,1	24%
R2	180	0,5	54	18	3,0	33%
R3	960	0,8	126	60	2,1	48%
S1	297	0,5	56	30	1,9	53%
S2	1176	0,8	106	74	1,4	69%
Food Court J	7228	1,3	350	278	1,3	79%
Food Court L	3133	0,9	550	174	3,2	32%
Canteen	1235	0,5	250	131	1,9	53%
Hall A	2485	2,5	480	50	9,7	10%
Hall B	2495	0,8	530	156	3,4	29%
Hall C	1605	1,0	380	80	4,7	21%

16 eating establishments



Acoustical capacity as a reference



Recommendations

- With less than 4 m^2 absorption per person the A-weighted noise level may exceed 71 dB and the quality of vocal communication is *Insufficient*
- For *Sufficient* conditions, the minimum volume per person should be ≈ $T \cdot 20$ (m^3)
- The limit for *Sufficient* conditions is the **Acoustical Capacity** calculated as

$$N = \frac{V}{20 \cdot T}$$

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Conclusion

- Most eating establishments have a capacity (number of seats) that exceeds the **Acoustical Capacity**, i.e. *insufficient* conditions when fully occupied
- *Satisfactory* conditions can be expected when the number of people is less than 50% of the **Acoustical Capacity**
- The **Acoustical Capacity** should be labelled at the entrance to restaurants and other eating facilities