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Multiconsult



Hva er tilfredsstillende lydisolasjon mellom boliger?

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Ref.: BNAM 2016, Stockholm



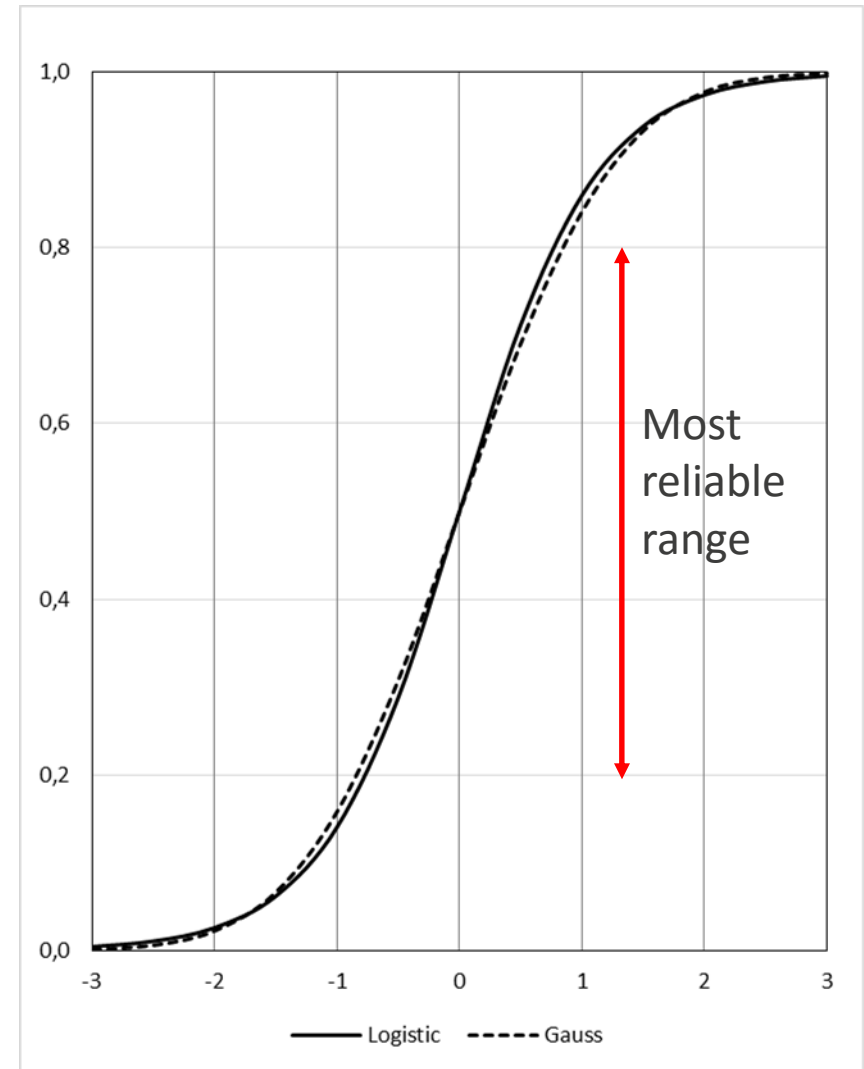
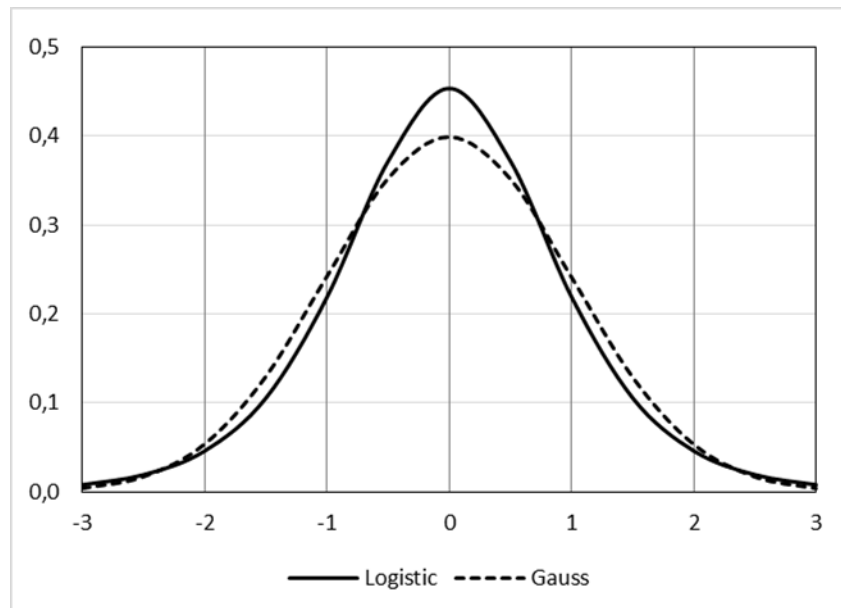
Outline

- General dose-response curves
- New Norwegian socio-acoustic investigation
- Selected results on sound insulation
- Normalized and standardized measures of sound insulation
- Percentage satisfied derived from dose-response curves
- Suggested relationships between sound insulation requirements and percentage satisfied

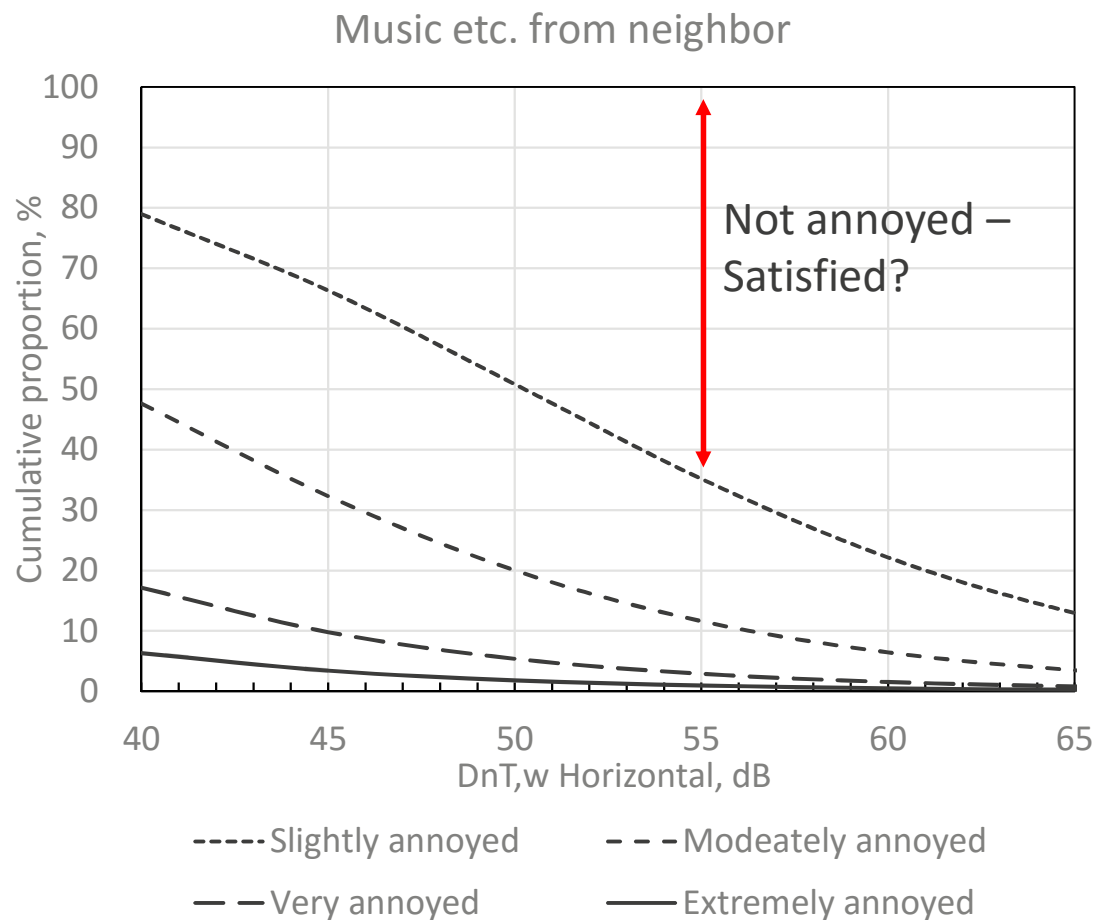


Logit analysis

- Assumed distribution of data:
- Close to – but not exactly – the normal distribution (Gauss)



Example dose-response curves



Logit analysis

NB: The curves are identical, but shifted along the dB axis



Type of study		Range of acoustic parameter (dB)	Slope of regression line <i>A</i> (% / dB)	Offset of regression line <i>B</i> (%)	Correla- tion coef- ficient <i>r</i>	Number of data points <i>n</i>	Number of interviews <i>N</i>
Airborne sound							
Insulation							
Langdon [1]	<i>P</i>	43-57	-4.43	263	-0.76	20	917
	<i>G</i>	-	4.27	-184	0.79	-	-
Bodlund [2]	<i>P</i>	54-61	(-10.98)	626	-0.43	11	330
	<i>G</i>	-	(10.47)	-526	0.43	-	-
Weber [4]	<i>P</i>	44-61	-3.73	233	-0.86	13	<471
Bradley [5]	<i>P</i>	39-60	(-2.17)	130	-0.28	98	98
Impact sound							
Pressure level							
Bodlund [3]	<i>P</i>	37-70	4.29	-222	0.75	22	464
	<i>G</i>	-	-4.09	282	-0.75	-	-
Weber [4]	<i>P</i>	26-56	(0.18)	-2.4	0.26	16	471
	<i>G</i>	-	(-1.24)	126	-0.56	-	-

Slopes of dose-response curves are close to 4% point per dB for results with $|r| > 0.7$.

Linear regression analysis in the middle range 20 – 80%

Rindel, J. Building Acoustics vol. 5 (1999)



Evaluation of sound conditions in dwellings

June 2015 - February 2016

- Evaluation of current requirements for airborne and impact sound insulation, noise from building services and from environmental noise sources
- Cooperation between Sintef Byggforsk, Institute of Transport Economics and Multiconsult.
- Main contents:
 - Review of the relevant literature
 - Collection of results from field measurements
 - Questionnaire about sound conditions
- Analysis of 702 replies from about 600 addressees with measured data



Measured airborne and impact sound insulation

Normalized and standardized

	Horizontal				Vertical			
	R'_w	D_{nT}	$R'_{w,50}$	$D_{nT,50}$	R'_w	D_{nT}	$R'_{w,50}$	$D_{nT,50}$
Number	355	296	346	296	394	366	354	349
Mean, dB	56,8	58,6	53,8	55,4	61,6	61,0	58,7	57,8
Difference, dB	1,8		1,6		-0,6		-0,9	

	Vertical			
	$L'_{n,w}$	$L'_{nT,w}$	$L'_{n,w,50}$	$L'_{nT,w,50}$
Number	473	411	439	402
Mean, dB	49,4	45,4	53,7	50,1
Difference, dB	4,0		3,6	



Normalized and standardized measures

$$D_{nT} = R' + 10 \log \left(\frac{0.32 \cdot V}{S} \right), \text{ (dB)}$$

V/S (m)	2,5	3,2	4	5	6,3	8	10
10 log (0.32 V/S), dB	-1	0	1	2	3	4	5

Vertical: -0.9 ; -0.6 dB Horizontal: 1.6 ; 1.8 dB

$$L'_{nT} = L'_n - 10 \log \left(\frac{0.32 \cdot V}{A_0} \right), \text{ (dB)}$$

V (m³)	20	25	32	40	50	63	80	100
-10 log (0.32 V/10), dB	2	1	0	-1	-2	-3	-4	-5

Vertical: -3.6 ; -4.0 dB



Three questions (out of 36)

“Thinking about the last 12 months, when you are at home, how much are you annoyed of noise from ... ? Not at all – Slightly – Moderately – Very – Extremely – – Not relevant”

- Speech, TV, computer game, etc. through floor/wall against neighbour
- Loud music with bass and drums through floor/wall against neighbour
- Footfall noise from neighbour living upstairs: walking, running, jumping, moving furniture, impact and strikes against floor etc.



Results, airborne sound insulation / speech Annoyance for mean sound insulation

Speech	Horizontal				Vertical			
	R'_w	$R'_{w,50}$	D_{nT}	$D_{nT,50}$	R'_w	$R'_{w,50}$	D_{nT}	$D_{nT,50}$
Number	355	346	296	296	394	354	366	349
Min, dB	46	45	45	44	50	50	52	51
Max, dB	64	63	65	64	69	68	70	69
Mean, dB	56,8	53,8	58,6	55,4	61,6	58,7	61,0	57,8
Standard dev, dB	3,0	2,8	4,0	3,0	4,3	2,6	4,2	2,4
Slightly annoyed	19,5 %		19,6 %		22,9 %		22,3 %	
Moderately annoyed	6,6 %		6,7 %		9,3 %		8,5 %	
Very annoyed	2,7 %		3,1 %		3,6 %		3,8 %	
Extremely annoyed	0,3 %		0,3 %		0,5 %		0,5 %	

Speech: 7 – 9% annoyed moderately or more



Results, airborne sound insulation / music Annoyance for mean sound insulation

Music	Horizontal				Vertical			
	R'_w	$R'_{w,50}$	D_{nT}	$D_{nT,50}$	R'_w	$R'_{w,50}$	D_{nT}	$D_{nT,50}$
Number	355	346	296	296	394	354	366	349
Min, dB	46	45	45	44	50	50	52	51
Max, dB	64	63	65	64	69	68	70	69
Mean, dB	56,8	53,8	58,6	55,4	61,6	58,7	61,0	57,8
Standard dev, dB	3,0	2,8	4,0	3,0	4,3	2,6	4,2	2,4
Slightly annoyed	27,8 %	26,4 %	25,4 %	24,8 %	27,3 %	25,4 %	25,4 %	26,5 %
Moderately annoyed	8,5 %	8,2 %	7,6 %	7,4 %	9,4 %	9,2 %	9,3 %	9,6 %
Very annoyed	1,8 %	1,7 %	1,8 %	1,8 %	3,2 %	2,8 %	3,0 %	2,9 %
Extremely annoyed	0,5 %	0,5 %	0,6 %	0,6 %	0,7 %	0,8 %	0,8 %	0,9 %

Music: 8 – 10% annoyed moderately or more



Results, impact sound

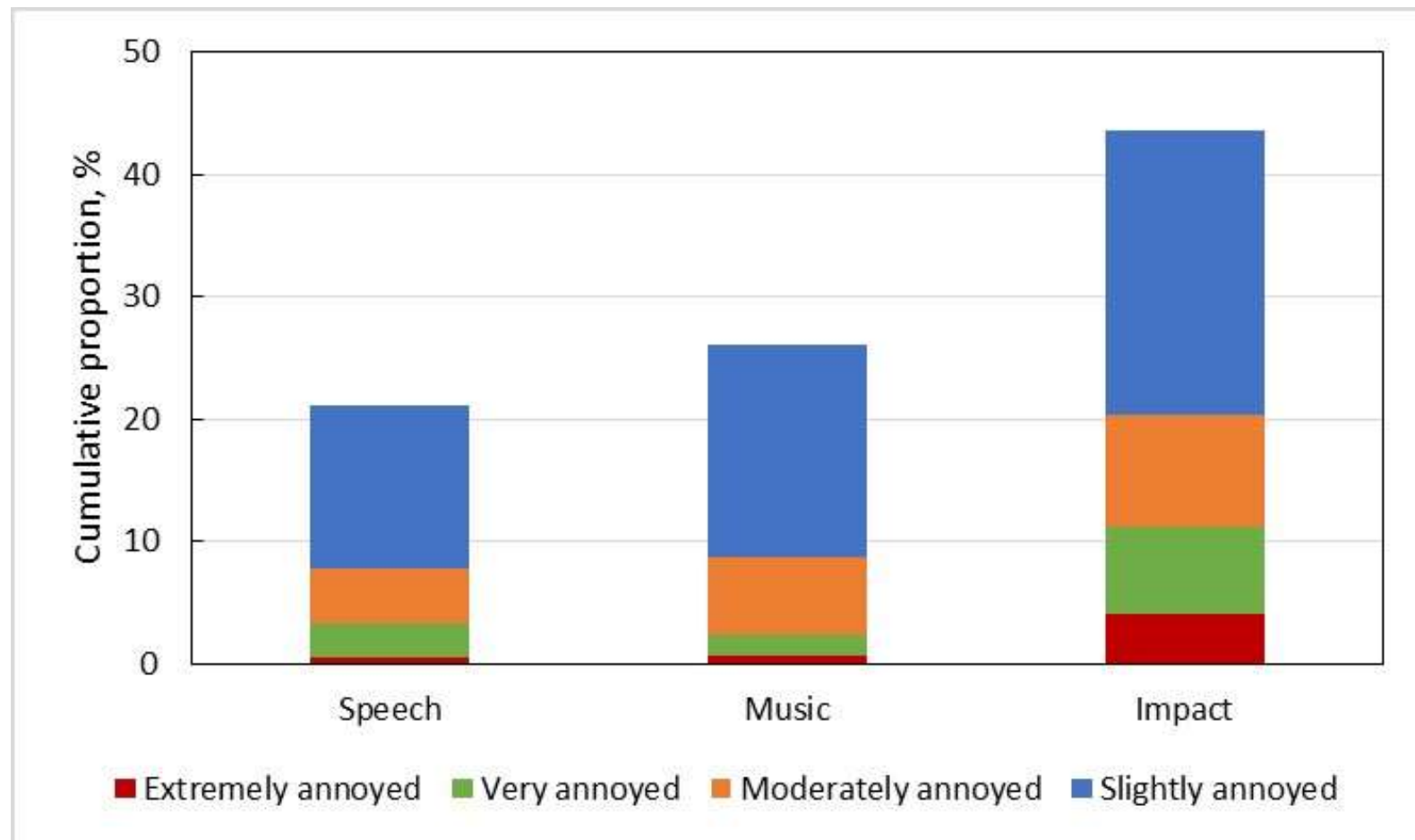
Annoyance for mean sound insulation

Impact	Vertical			
	$L'_{n,w}$	$L'_{n,w,50}$	$L'_{nT,w}$	$L'_{nT,w,50}$
Number	473	439	411	402
Min, dB	41	44	38	40
Max, dB	60	61	56	57
Mean, dB	49,4	53,7	45,4	50,1
Standard dev, dB	4,1	3,0	5,0	2,0
Slightly annoyed	45,5 %	42,6 %	43,3 %	42,8 %
Moderately annoyed	22,2 %	19,9 %	20,0 %	19,1 %
Very annoyed	12,3 %	11,2 %	11,2 %	10,2 %
Extremely annoyed	4,5 %	3,8 %	4,3 %	3,8 %

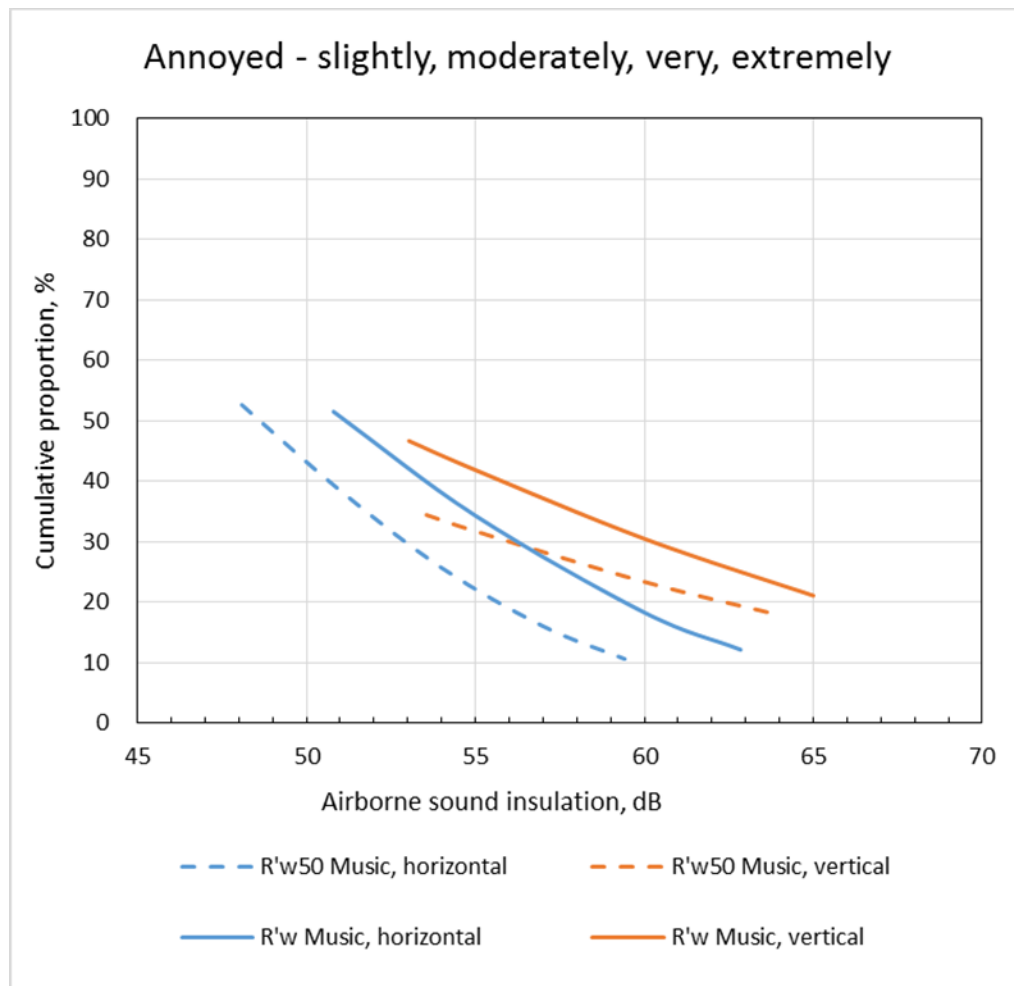
Impact sound: 19 –22% annoyed moderately or more



Annoyance due to speech, music and impact sound related to the mean sound insulation

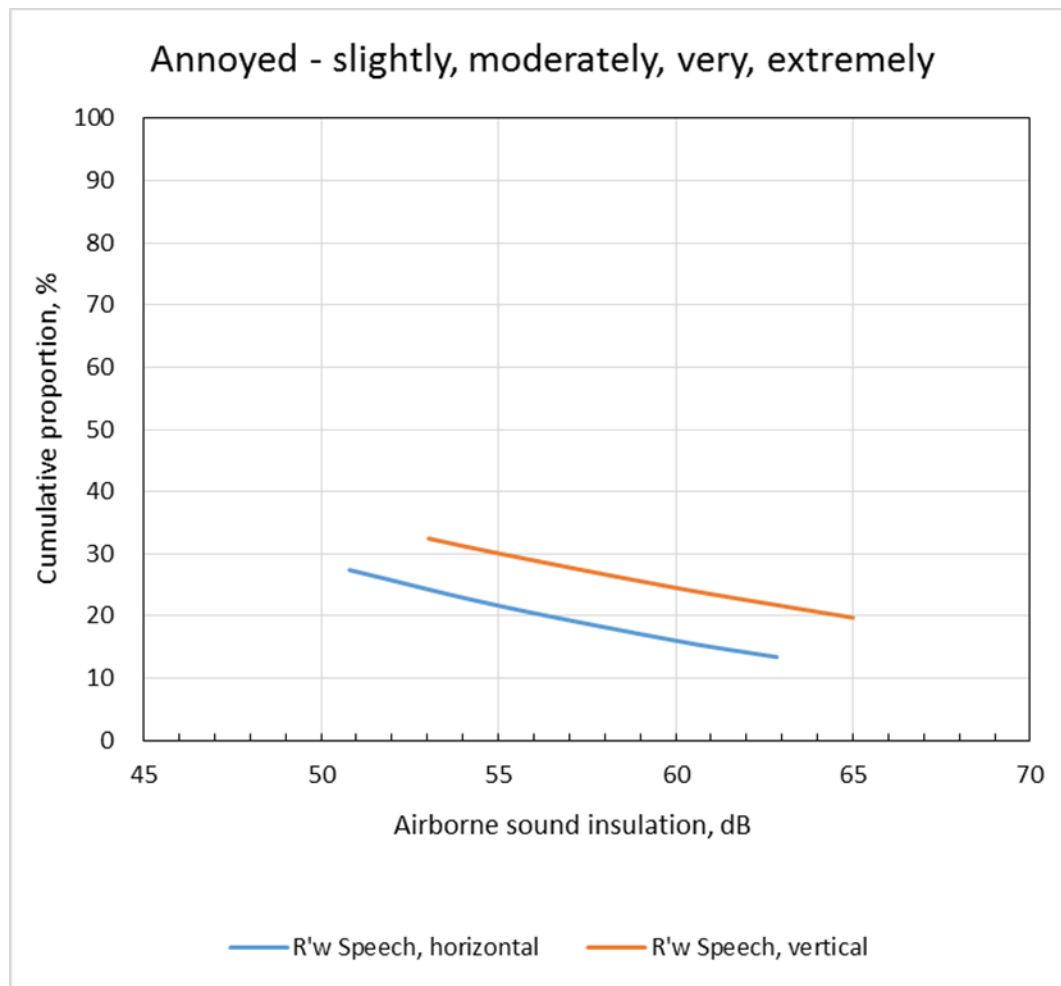


Music



- Horizontal direction is most important (blue curves)
- On average 5 dB better sound insulation in vertical direction
- $C_{50-3150} \cong -3$ dB

Speech



- Horizontal direction is most important (blue curves)
- Speech is less annoying than music

Some observations – airborne sound

- Airborne sound insulation
 - Vertical ca. 5 dB better than horizontal
 - Music with bass more annoying than speech, TV etc.

	Horizontal	Vertical
Music	+	-
Speech	-	-

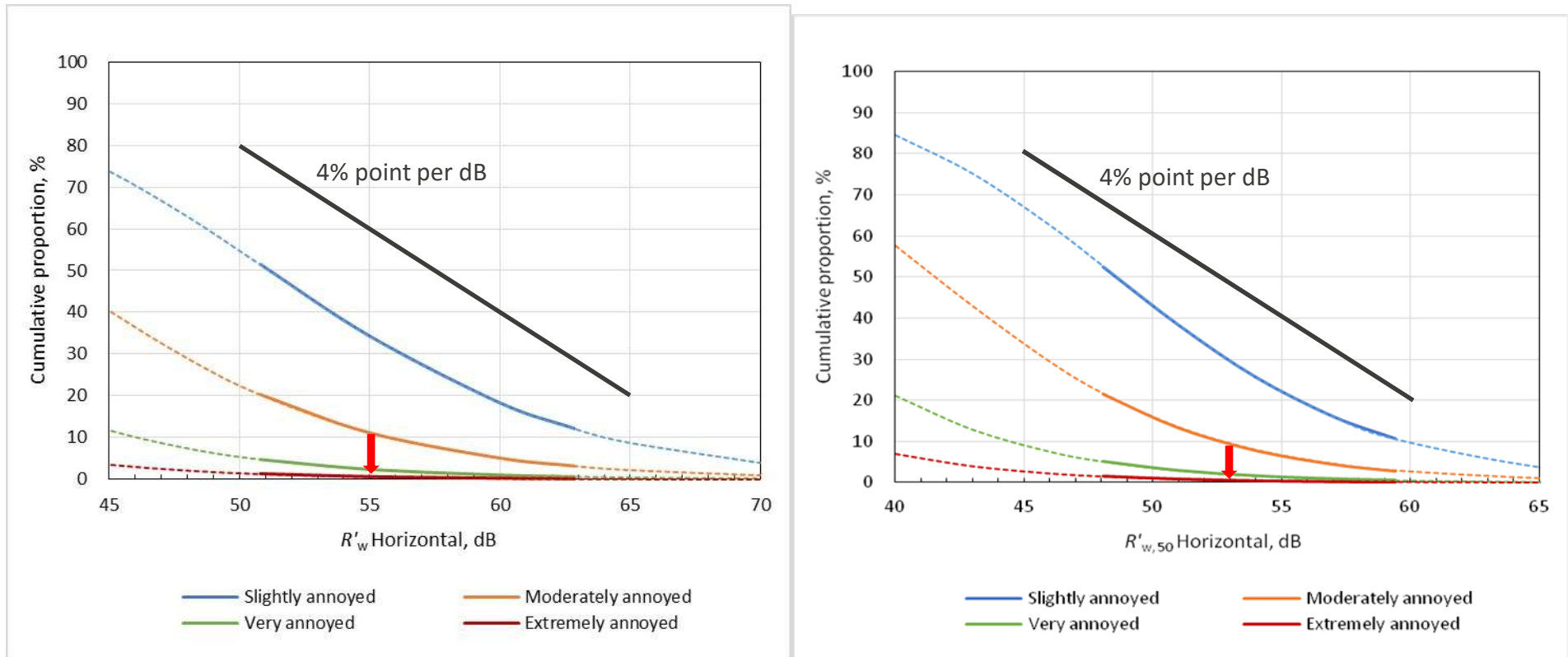


Dose-response curves for airborne sound insulation

Horizontal – annoyance by music with bass and drums

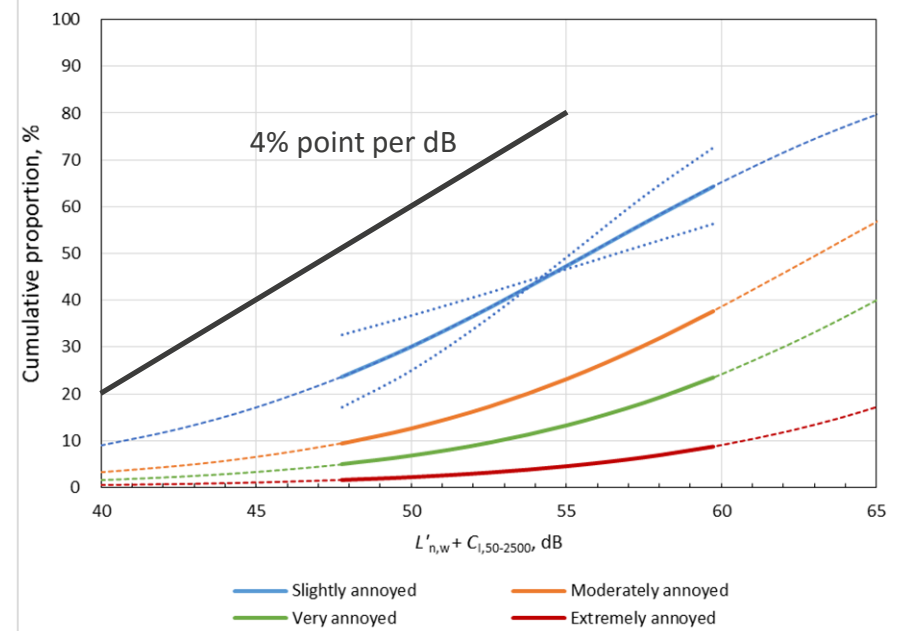
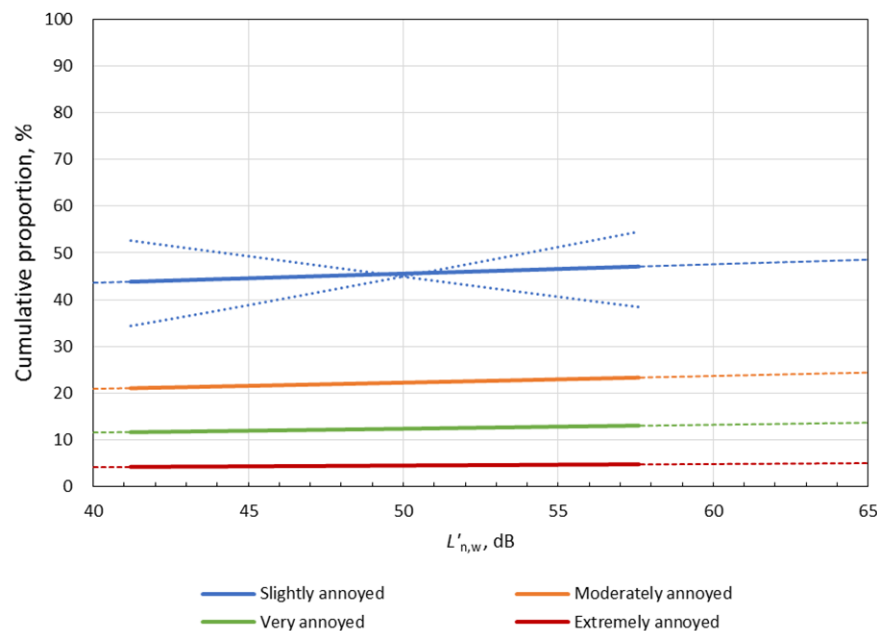
10% annoyed moderately or more for $R'_w = 55$ dB and $R'_{w,50} = 53$ dB

Equal annoyance when $R'_{w,50} = R'_w - 2$ dB



Dose-response curves for impact sound

- No significant correlation unless frequencies down to 50 Hz are included
 - Equally valid for light-weight and heavy constructions
 - $C_{l,50-2500}$ varies from -2 to +12 dB



Some results / observations

- 50 Hz must be included in impact sound measurements
 - otherwise no correlation with subjective evaluation. Both lightweight and heavy constructions
- The slope in middle range of the dose-response curves are close to 4% point per dB for R'_w and $R'_{w,50}$ and $L'_{nw,50}$
 - in good agreement with results from previous investigations



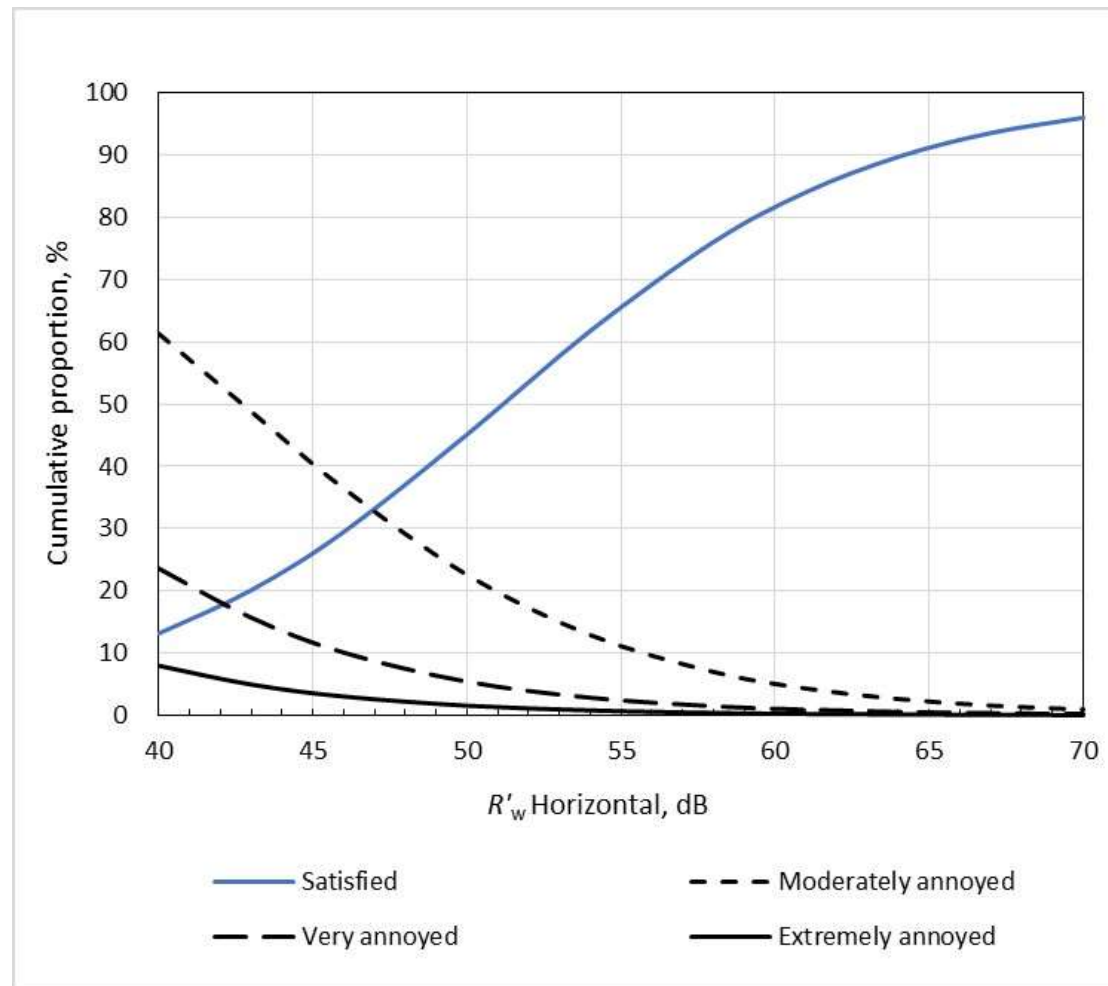
Application of dose-response curves

- Which curve to look at?
 - Highly annoyed (very + extremely annoyed)
 - the curve is rather flat (typically below 10%)
 - Setting a limit is with high uncertainty
 - Satisfied (100% - percentage annoyed (all levels))
 - The curve is near the steepest slope (typically between 50 and 80%)
 - The best available criterion for setting a limit
- Extrapolation outside the 95% range of measured data
 - The curves are most reliable near the average of measured data (the turning point)
 - The slope may be slightly adjusted to meet 4% point per dB

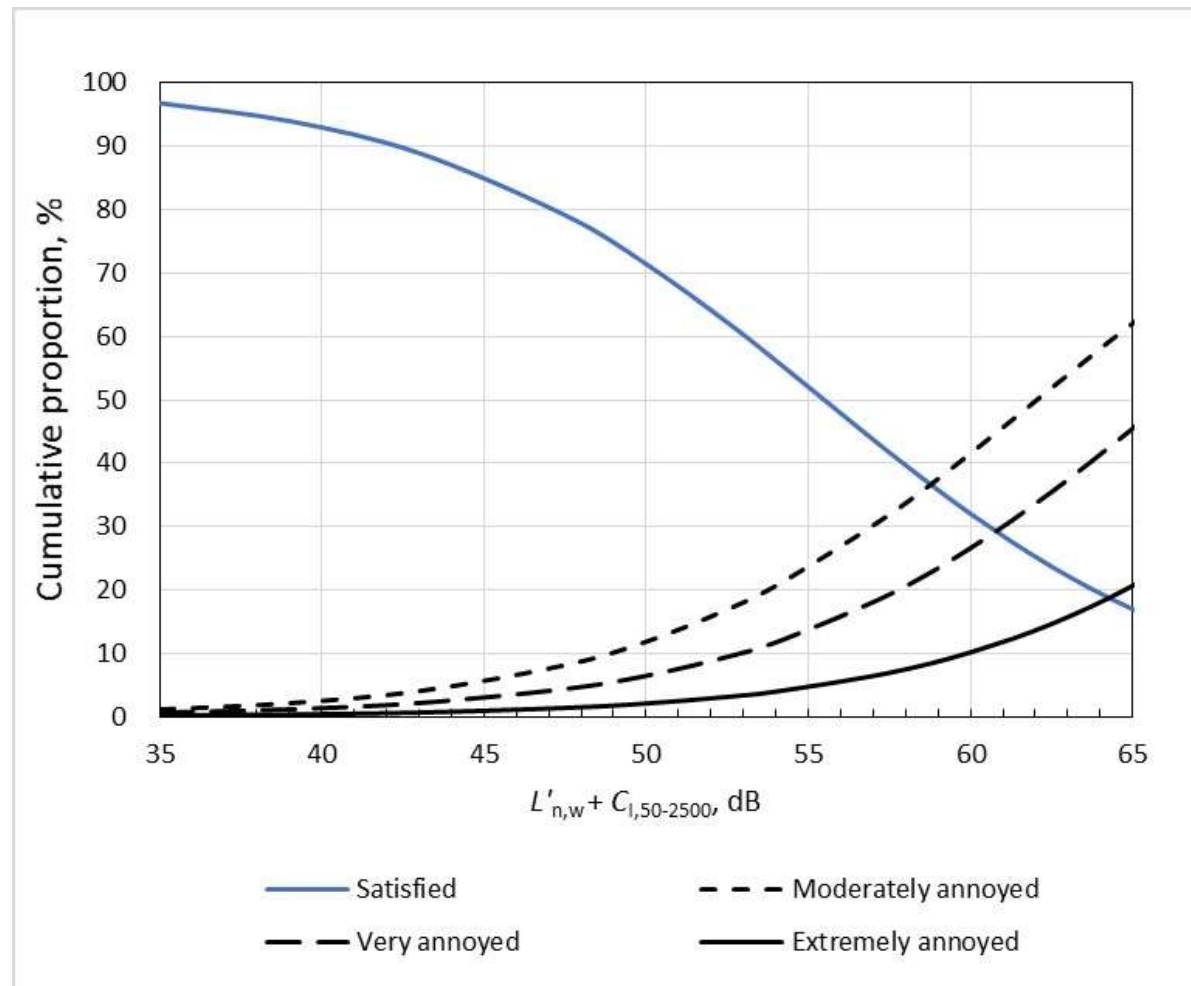


Dose-response curves (no adjustment needed)

Airborne sound insulation



Dose-response curves (slightly adjusted slope) Impact sound pressure level



Limits of sound insulation for various degrees of satisfaction

Percent satisfied (not annoyed), %		90	80	70	60	50	40	30	20
Percent annoyed (moderately + very + extremely), %		3	8	12	18	25	35	45	55
Normalized airborne sound insulation	R'_w , dB	64	59	56	53,5	51	48,5	46	43
	$R'_w + C_{50-3150}$, dB	62	57	54	51,5	49	46,5	44	41
Standardized airborne sound insulation	$D_{nT,w}$, dB	66	61	58	55,5	53	50,5	48	45
	$D_{nT,w} + C_{50-3150}$, dB	64	59	56	53,5	51	48,5	46	43
Impact sound insulation	$L'_{n,w} + C_{l,50-2500}$, dB	42,5	47,5	50,5	53	55,5	58	60,5	63,5
	$L'_{nT,w} + C_{l,50-2500}$, dB	39	44	47	49,5	52	54,5	57	60



Limits of sound insulation for various degrees of satisfaction

NS 8175 - Class B - Class C

Percent satisfied (not annoyed), %		90	80	70	60	50	40	30	20
Percent annoyed (moderately + very + extremely), %		3	8	12	18	25	35	45	55
Normalized airborne sound insulation	R'_w , dB	64	59	55	53,5	51	48,5	46	43
	$R'_w + C_{50-3150}$, dB	62	58	54	51,5	49	46,5	44	41
Standardized airborne sound insulation	$D_{nT,w}$, dB	66	61	58	55,5	53	50,5	48	45
	$D_{nT,w} + C_{50-3150}$, dB	64	59	56	53,5	51	48,5	46	43
Impact sound insulation	$L'_{n,w} + C_{l,50-2500}$, dB	42,5	48	50,5	53	55,5	58	60,5	63,5
	$L'_{nT,w} + C_{l,50-2500}$, dB	39	44	47	49,5	52	54,5	57	60



Conclusion

- Airborne sound insulation – the weakest part (most important) is the horizontal direction in combination with music with bass and drums
- Impact sound insulation – the inclusion of 50 Hz is necessary
- Generalised dose-response curves have been suggested –
 - Based on the findings from the Norwegian survey
 - Using a slope of 4% point per dB in the middle range of the dose-response curves

