EMPIRICAL MODELS FOR PREDICTING NOISE LEVELS AND REVERBERATION TIMES IN INDUSTRIAL WORKROOMS

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INTRODUCTION

There is currently a large gap between performance and complexity in most industrial noise-level prediction models. Hodgson has proposed an empirical model which bridges this gap [1]. However, it does not allow for variable room dimensions, fitting densities and absorptions coefficients. In this paper a new prediction model is proposed which includes adjustable parameters for these factors. In addition, an empirical model for calculating reverberation times in industrial workrooms is presented.

DATA

The models were developed from measurements of sound propagation curves and reverberation times in thirty industrial workrooms using multi-variable regression analysis. An industrial workroom sound-propagation curve (SPC) is the variation with distance from an omnidirectional point source of the sound pressure level minus the source sound power level. Regressions to these data yielded the slope and intercept of the SPC - approximated as a single straight-line segment when plotted on a log-distance scale. Reverberation times used in the empirical model development were octave-band spatially-averaged values. Fitted workspaces displayed additional apparent absorption due to the fittings. This absorption was added to the absorption already present on the hard floor and divided by the floor area to give the effective fitted-floor absorption coefficient, α_eff.

REVERBERATION-TIME PREDICTION

Reverberation times were predicted using the Eyring equation. The effect of fittings was modelled as additional room surface absorption (α_eff). The relationship of α_eff to fitting density Q was calculated by linear regression of the form

$$\alpha\_eff = Slope \bullet Q + Intercept \qquad (1)$$

(results in Table 1) in which Q is defined as

$$Q = \frac{\Sigma SA}{4 \bullet V} \qquad (2)$$

as developed by Kuttruff [2], where ΣSA is the total exposed surface area of the fittings and V is the room volume.

NOISE-LEVEL PREDICTION

Using Tables 2, 3a and 3b the sound pressure level Lp(r) generated by a source is found by

$$Lp(r) = Lw + SPC.Intercept + SPC.Slope \bullet \log 10(r) \qquad (3)$$

where Lw is the sound power level of the source and r is the source/receiver distance. The standard deviations of the SPC prediction error obtained using Eq. (3) are shown in Table 5.

Table 1: Regression of α_eff vs. Q.

	Slope	Intercept	R^2	Standard Error
125 Hz	4.52	0.110	0.60	0.079
250 Hz	5.80	0.017	0.70	0.087
500 Hz	4.32	0.099	0.91	0.035
1 kHz	2.79	0.131	0.78	0.036
2 kHz	2.28	0.140	0.85	0.024
4 kHz	1.94	0.135	0.83	0.022

Table 2: Parameter coefficients of the SPC slope model.

Coef.	S1	S2	S3	S4	S5	S6	S7
125 Hz	-16.09	-12.11	195.9	-0.037	-5.08	14.95	-91.94
250 Hz	-21.94	-14.32	225.4	-0.028	-3.63	18.77	-102.3
500 Hz	-29.92	-12.53	194.1	-0.007	-2.33	17.74	-87.69
1 kHz	-26.89	-12.54	186.8	0.032	-9.79	17.96	-81.11
2 kHz	-24.88	-8.46	127.8	0.131	-11.60	15.94	-60.52
4 kHz	-19.21	-9.16	146.0	0.135	-11.88	13.18	-70.81

Table 3a: Parameter coefficients of the SPC intercept model.

Coef.	I1	I2	I3	I4	I5
125 Hz	-6.32	5.84	-86.7	0	5.03
250 Hz	-2.96	6.58	-98.0	0	5.00
500 Hz	19.4	6.46	-99.8	-121	5.13
1 kHz	-16.5	8.61	-127	48.3	12.4
2 kHz	-18.2	5.59	-85.5	72.2	0
4 kHz	-18.3	9.74	-155	37.1	0

Table 3b: Parameter coefficients of the SPC intercept model.

Coef.	I6	I7	I8	I9	I10
125 Hz	0	-8.33e-5	0	3.10e-3	21.4
250 Hz	0	-6.25e-5	0	2.50e-3	25.5
500 Hz	0	5.64e-5	0	1.14e-3	27.9
1 kHz	-9.04	-1.34e-4	0	1.82e-3	41.1
2 kHz	-10.1	0	-4.87e-4	0	29.0
4 kHz	-21.4	0	-8.40e-4	2.47e-3	65.9

Table 4: Description of SPC model parameters.

Parameter	Description
S1	Factor including air, surface and fitting absorptions
S2, I2	Room height
S3, I3	Log10(room height)
S4	1/Q
S5, I5	Average fitting height/room height
S6, I6	Room surface area / room volume
S7, I10	Constant
I1	Effective absorption of fitted floor (α_eff)
I4	Q
I7	Room volume
I8	Room surface area
I9	α_eff • floor area

Table 5: Performance of new SPC model.

Room Type	All	Type 1	Type 2	Type 3	Type 4
Fittings	-	No	No	Yes	Yes
Acoustical Treatments	-	No	Yes	No	Yes
Slope	1.05	0.99	0.85	1.09	1.33
Intercept	0.93	1.05	0.99	0.78	1.04

[1] "Preliminary simplified models for predicting sound propagation curves in factories," M.R. Hodgson, Canadian Acoustics 20 (3), 37-38 (1992).

[2] Kuttruff, Room Acoustics (Elsevier Applied Science, New York, 1991).