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A STOCHASTIC TECHNIQUE FOR THE PREDICTION OF NOISE FROM CONSTRUCTION SITES

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ABSTRACT
For an assessment of site noise to become routine in the preliminary project-planning phase, alternative methods of prediction are required. A simple method for the prediction of open site industrial noise is proposed. The basis of this method is the replacement of a distribution of discrete sources by a point source of the same equivalent total sound power. However this work extends the principle to the quantification of the uncertainty in the predicted immissions by the application of stochastic modelling.

1 - INTRODUCTION
Although noise from construction sites is recognized as a potential problem, current prediction techniques are unsuitable for use by developers and contractors for estimating the magnitude of the problem and costing possible remedial measures when tendering for work. Carpenter [1] has demonstrated how at the planning stage of new developments, the level of detail required for deterministic predictions is not available. For an assessment of site noise to become routine in the preliminary project-planning phase, alternative methods of prediction are required. These prediction methods would require comparatively granular data and produce predictions of noise levels with quantifiable uncertainty. Lewis and Gibbs [2] have described one such approach, where through the application of stochastic modelling the noise sources and propagation processes can be represented statistically. This paper reports an extension of the earlier work leading to a simple method for the prediction of open site industrial noise. The basis of the proposed simplified estimation method is the replacement of a distribution of discrete sources by a point source of the same equivalent total sound power. However this work extends the principle to the quantification of the uncertainty in the predicted immissions by the application of stochastic modelling.

2 - THE STOCHASTIC MODEL
The dimensions of a simulated rectangular site were defined by X and Y, and sites included all 25 configurations of dimensions 50, 100, 150, 200 and 250m. Up to four stochastic sources were considered to be positioned at random locations within the boundary. The sound power of each stochastic source was allowed to vary randomly from full power, to tick-over, to off with a probability density function of 0.6: 0.2: 0.2 respectively. The equivalent sound power level of a stochastic source is therefore given by:

$$L_{Weq}=10\log_{10}\left[0.6\times 10^{L_{w_1}/10}+0.2\times 10^{L_{w_2}/10}+0.2\times 10^{L_{w_3}/10}\right]\ dBA \quad (1)$$

where L_{w_1} is the full power level, L_{w_2} is the tick-over sound power level, and L_{w_3} is the off sound power level. Tick-over was taken as full power minus 10dBA, off as 0dBA, and 12 combinations of stochastic source powers were considered. The total equivalent sound power level of a site L_{Weq} is then given by:

$$L_{Weq}=10\log_{10}\left[10^{Lw_{eq1}/10}+10^{Lw_{eq2}/10}+10^{Lw_{eq3}/10}+10^{Lw_{eq4}/10}\right]\ dBA \quad (2)$$

where $L_{w_{eqi}}$ is the equivalent sound power level of respective sources.
For each random position and sound power variation the sound pressure level at a series of receivers a distance R along a normal to the site X boundary through the site centre was calculated assuming

hemispherical propagation over a hard plane. Receivers were considered at distances 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, and 1024m from the boundary. The mean and standard deviation in sound pressure level was determined at each of the 11 receivers, for each of the 25 sites, for each of the 12 stochastic source combinations.

3 - PROPAGATION FROM EXTENDED SOURCES

The stochastic data were analysed to investigate the variation of fall off with doubling of receiver distance as a function of site aspect ratio X/Y in order to establish an empirical correction. The fall off of mean sound pressure level with doubling of receiver distance was found to vary with the number of sources in the stochastic simulation with the 4 source combinations closest approximating to a point source for a site aspect ratio of 1. Figure 1 shows the fall off with doubling of distance for all the stochastic combinations of sources and sites together with the following expression over an aspect ratio range of 0.1 to 10:

$$f = -1.5\log_{10}\left(\frac{X}{Y}\right) + 6 \quad (3)$$

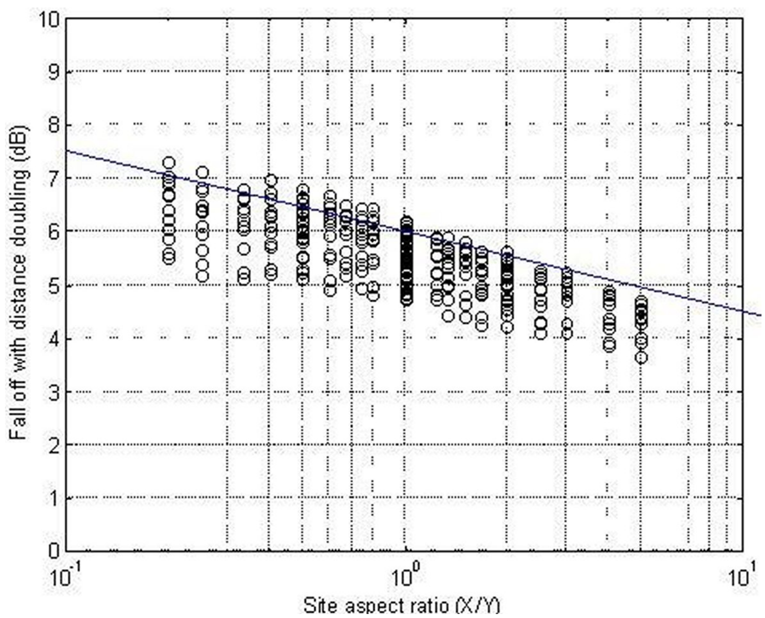

Figure 1: The fall off with doubling of distance as a function of aspect ratio.

The stochastic data was further analysed to derive a relationship between the site aspect ratio, the equivalent sound power level of the site and the mean sound pressure level at a receiver. By analogy with propagation from a point or a line source an expression of the form

$$L_1 = L_W + m\log_{10}\left(\frac{X}{Y}\right) + c$$

was hypothesised, where L_1 is the mean sound pressure level at 1m from the site centre, L_W is the equivalent sound power level of the site, and m and c are constants. Figure 2 shows the extrapolations to a point 1m from the centre of the site of the mean sound pressure level L_1 minus the equivalent sound power of site L_W for 2,3 & 4 sources, together with the following expression:

$$L_1 - L_W = -15\log_{10}\left(\frac{X}{Y}\right) - 8 \quad (4)$$

These two expressions can be combined to give the following expression for the estimation of mean sound pressure level $L_p(r)$ at a receiver distance r from the centre of a site of total equivalent sound power level L_W and dimensions X and Y an aspect ratio range of 0.1 to 10:

$$L_p(r) = L_W - 20\log_{10}(r) - 15\log_{10}\left(\frac{X}{Y}\right) + 5\log_{10}(r)\log_{10}\left(\frac{X}{Y}\right) - 8 \quad (5)$$

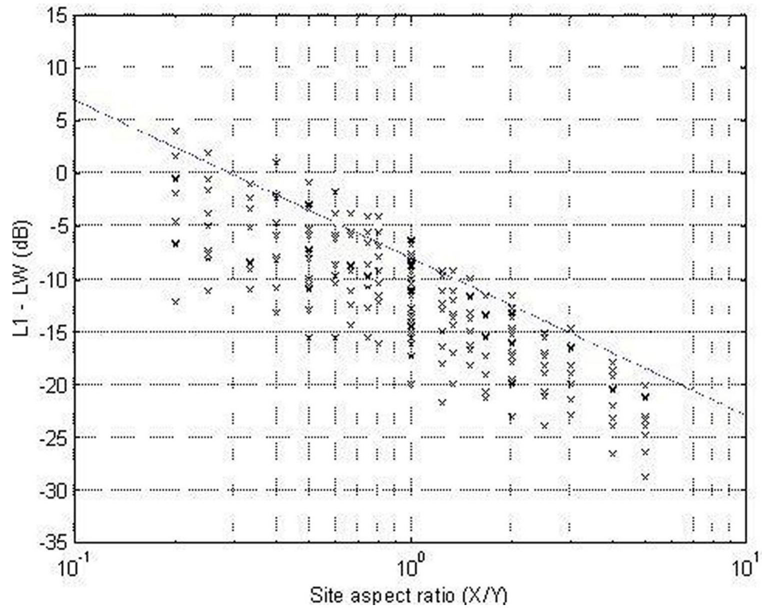

Figure 2: The mean sound pressure level L_1 minus the equivalent sound power of site L_W at 1m from the centre of the site of as a function of aspect ratio.

4 - ESTIMATION OF THE STANDARD DEVIATION

The standard deviation estimation method is based upon the assumption that the immissions take the form of a normal distribution [3]. For normal and moderately skewed distributions the maximum and minimum sound pressure levels at a receiver will occur at approximately ±4 standard deviations from the mean respectively. For the stochastic model the maximum sound pressure level $L_{p\max}(r)$ at a receiver will occur when all the sources are operating at full power at the closest point to the receiver on the boundary. Conversely the minimum sound pressure level $L_{p\min}(r)$ at a receiver will occur when all the stochastic sources are off and only background noise is present. The standard deviation s is therefore estimated by the expression:

$$s(r) = \frac{L_{p\ \max}(r) - L_{p\ \min}(r)}{8} \qquad (6)$$

where $L_{p\max}(r)$ is calculated using equation (5) assuming the maximum source powers acting from the closest point on the boundary to the receiver, and $L_{p\min}(r)$ is the background noise level.

5 - COMPARISON OF PREDICTIONS AND SIMPLE ESTIMATIONS

Stochastic predictions and simple estimates mean sound pressure level and standard deviations are compared in figure 3. The simple estimate was observed to perform best for many sources of similar mean sound powers for site aspect ratios (X/Y) closer to 1. For this source combination the mean of the absolute difference in sound pressure level is less than 1dBA and the maximum difference 1.8dBA. For sites of all dimensions for this source combination the mean of the absolute difference in standard deviations is less than 1dBA and the maximum difference 3dBA.

6 - CONCLUSIONS

A method has been developed based upon stochastic modelling for the estimation of the mean sound pressure level at a receiver a distance from a construction site. The technique provides an assessment of the accuracy of the prediction, yet is simple and undemanding to put into practice. Developments to the simple estimation method necessary to enhance its use as a strategic planning tool include the effects of screening, ground attenuation and meteorological conditions.

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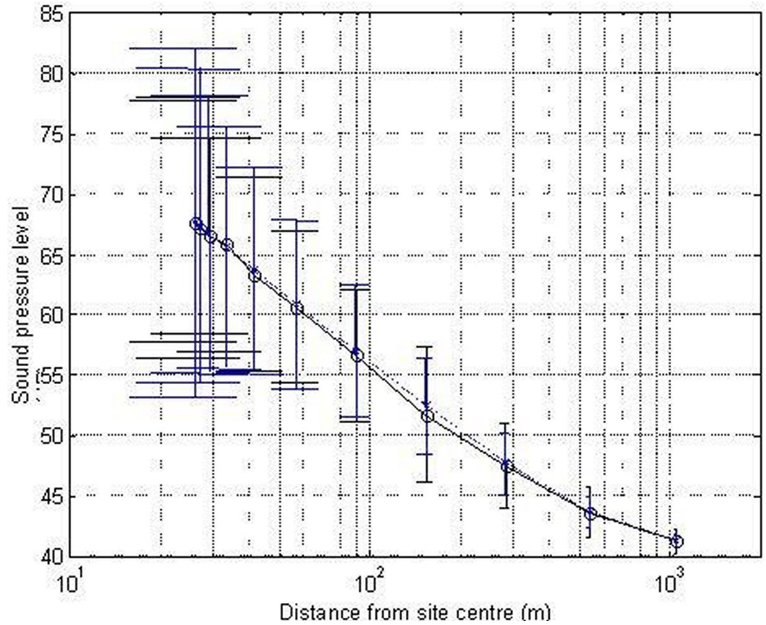

Figure 3: Comparison of stochastic predictions and simple estimates of mean sound pressure level and standard deviations.

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