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TRAFFIC NOISE LEVEL PREDICTION BY COMPUTER SIMULATION

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Introduction.

Although the noise levels arising from streams of freely flowing traffic can be estimated satisfactorily, the current prediction method[1] is far less precise in dealing with road intersections, traffic interruptions and congestion. This paper describes a computer simulation model, using Monte Carlo techniques, which can deal with complex traffic conditions and road configurations and requires input parameters that can be easily predicted or quantified. The advantages of the method are that (i) single or complex noise parameters relating to traffic streams can be determined from the noise level characteristics of single vehicles, (ii) controlled studies of individual traffic parameters (flow, composition etc.) can be made to determine how they influence the overall traffic noise.

Basic model characteristics.

Traffic noise arises ultimately from the combination of the noise levels generated by individual vehicles in the traffic stream and depends on vehicle velocity and type, the vehicle/observer separation, and the ground cover between the observer and the vehicles. The noise levels from the traffic stream as a whole depend on the composition and headway distribution of the vehicles in the stream, as well as other influensing factors such as noise barriers, the presence of buildings and the road geometry etc.

This simulation program has been designed to mimic the measurement technique used by most commercial noise monitoring instruments. Level contributions from individual pass-by curves (Figure 1) are sampled instantaneously and integrated at regular (one second) intervals producing a cumulative distribution of levels for the vehicles considered, from which L_{10}, L_{50} and L_{90} values can be determined.

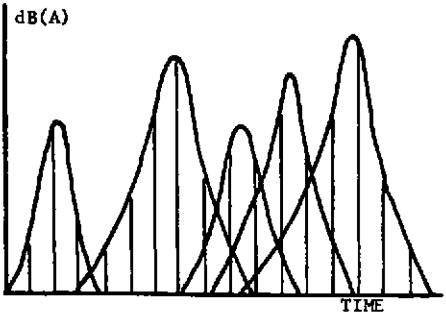

Figure 1 Summation of individual pass-by curves.

Essential model parameters.

The fixed parameters in our model are,

(i) vehicle classification; either 'light' (U.W. 1525 kg) or 'heavy'.

(ii) level/velocity relationship; the peak noise level (L_R) from a vehicle travelling at velocity V, which is detected at some reference distance R from the vehicle, has been shown[2] to be of the form

$$L_R = \alpha \log_{10} V + \beta \qquad (1)$$

where α and β are constants, having values which depend on the vehicle category considered. From a study of approximately 1000 vehicles, at a distance of 1.7m, we have deduced that $\alpha = 29.9$ for both light and heavy vehicles, with β values of 29.8 and 38.0 for light and heavy vehicles respectively. Below 29 km/h a constant value of L_R is used (73.5 and 81.6 dB(A) for light and heavy vehicles

respectively).
(iii) attenuation characteristics; an empirical expression is incorporated in the program, based on field studies, which describes satisfactorily the observed attenuation of traffic noise over different ground surfaces,

$$\Delta L = -m_f \log_{10} d + K_f \qquad (2)$$

where ΔL is the attenuation in dB(A) for a source-receiver separation of d metre. The values of constants m_f, and K_f depend on the nature of the ground cover.

(iv) Vehicle arrival pattern; a displaced negative exponential distribution of the form,

$$t = \tau - (\bar{t} - \tau) \ln R \qquad (3)$$

is used to describe the time interval (t) between consecutive vehicles arriving at X (Figure 2). τ and $\bar{t}$ are the minimum and mean time delays respectively between consecutive vehicles. R is a pseudo-random number, $(0<R\leq 1)$, generated by the computer from a uniform distribution.

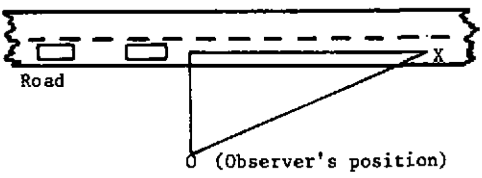

Figure 2 Vehicle detection point relative to observer.

Input data and program operation
The program requires for operation both general data (number of traffic lanes, microphone height, background noise level and the number of vehicles to be sampled) together with individual lane data (observer/lane centre distance, percentage of total and percentage of heavy vehicles in lane, velocity distributions for light and heavy vehicles).

The classification and introduction of vehicles into the program is organised by means of a pseudo-random number generator. The exact time, position and velocity of each vehicle at the instant when its noise level is first sampled, are calculated. Subsequently, the position and velocity of each vehicle are updated at one second intervals and the noise level sampling is continued until it falls below the background level, at which stage the next vehicle is considered. After sampling all the vehicles in a particular lane, the process is repeated lane by lane, up to a maximum of eight lanes. Having sampled all vehicles on the road, a cumulative distribution of the noise levels is then determined and the required noise indices computed. The program begins by sampling the vehicles in the nearest lane to the microphone and values of L_{10}, L_{50}, L_{90}, L_{eq} and are printed out for that lane. As each lane is considered, cumulative values of these noise indices are determined, thus allowing the contributions to the overall noise from traffic in different lanes to be observed.

The model described is essentially a hybrid of a Monte-Carlo technique, for the initial generation of vehicles on a road, and analytical techniques which generate the acoustical parameters of the vehicles and update their movements along the road. The hybrid technique makes efficient use of computing time and can be applied to problems involving complicated road geometries.

Freely flowing traffic predictions.
The noise from freely flowing traffic[1] can be predicted satisfactorily by the 'Calculation of Road Traffic Noise' issued in 1975. Although our model is designed for a wide range of traffic conditions and road configurations, the performance of the model was tested initially against the standard U.K.

prediction method for free-flow traffic.

Figure 3 compares the L_{10} predictions, 10m from kerbside, for a hypothetical two-lane road, with traffic flow rates of 500 to 3000 vehicles/h and 0%, 10% and 20% heavy vehicles per lane. Although the 54 model predictions show good agreement with values obtained using the standard method, our predictions tend to be slightly higher than those derived from the latter. This is in accord with comments[3] which suggest that the standard method tends to underpredict by a marginal amount.

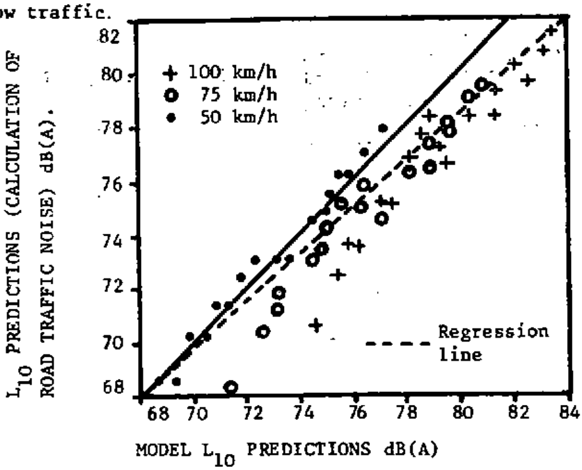

Figure 3 Comparison of L_{10} predictions for freely flowing traffic

In Table 1, hourly L_{10}, L_{50} and L_{90} values, measured at three sites adjacent to suburban dual carriageway roads carrying freely flowing 'real' traffic, are compared with the corresponding model predictions and the L_{10} values given by the standard method.

	L_{10} dB(A)			L_{50} dB(A)		L_{90} dB(A)	
		Predictions					
	Meas[d.]	Model	Std Mtd[1]	Meas[d.]	Model	Meas[d.]	Model
Site 1	81.1	79.5	79.1	69.4	71.5	61.4	62.3
Site 2	81.1	80.5	79.6	70.0	73.3	62.0	65.8
Site 3	80.2	78.5	77.8	69.0	69.3	55.9	58.5

Table 1 Comparison of measured and predicted levels.

In general, our model at this stage of refinement tends to underpredict L_{10} and to overpredict L_{50} and L_{90}, the latter being notoriously difficult to predict. However, the model predictions for L_{10} are better than those given by the standard method.

Interrupted traffic flow predictions.

To study the effect of traffic flow interruptions at road intersections, kerbside measurements were made along the arms of two different roundabouts. To simplify the problem, vehicles were assumed to decelerate from constant velocity, (V_0), at some distance from the STOP line of the intersection, to a minimum velocity, (V_m), at the STOP line and then to accelerate directly across the intersection until a constant velocity was again reached. This ignores queue formations and turning movements at the roundabout. The velocity (v) of a vehicle, distant x from the STOP line, is calculated from:

$$v = V_o \left[1 - f \exp^{-\lambda x}\right] \quad (4)$$

where λ is a constant for each lane, and $f = (V_o - V_m)/V_o$. This function can be integrated and the position and velocity of a vehicle on the road updated in the model every second. Figure 4 compares the measured levels and model predictions of L_{10} along one arm of an intersection and is typical of the results obtained along the other arms. Figure 5 gives an indication of the measured percentile levels for all four arms of the same intersection, compared with the corresponding model predictions.

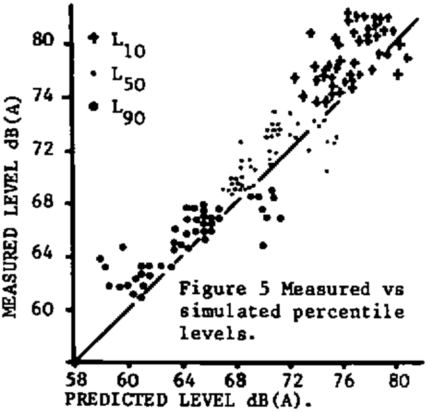

Figure 5 Measured vs simulated percentile levels.

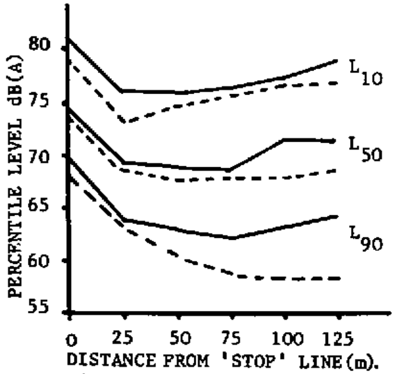

Figure 4 Comparison of measured and simulated percentile levels.

Conclusions.

On the basis of the results obtained so far, the computer simulation model described provides good agreement between measured and predicted L_{10} values for freely flowing traffic and for traffic passing through road intersections controlled by roundabouts. The L_{10} model predictions agree closely with those indicated by the standard U.K. method for freely flowing traffic conditions. The accuracy in predicting L_{50} and L_{90} is not yet satisfactory.

For the interrupted flow conditions at the two intersections considered, L_{10} values were predicted with a degree of accuracy which was similar to that of the U.K. standard method for freely flowing traffic conditions.

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References.

1. DEPARTMENT OF THE ENVIRONMENT, Calculation of road traffic noise, London, HMSO, 1975.
2. P.T. LEWIS, The noise generated by single vehicles in freely flowing traffic, Journal of Sound and Vibration, 1973, 30 (2), 191-206.
3. M.E. DELANY, D.G. HARLAND, R.A. HOOD and W.E. SCHOLES, The prediction of noise levels (L_{10}) due to road traffic, Journal of Sound and Vibration, 1976, 48 (3), 305-325.