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A STOCHASTIC MODEL FOR ROAD TRAFFIC NOISE

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1.0 INTRODUCTION

Current methods for the prediction of road traffic noise have relied primarily on regression analysis of field measurements, and as such must give adequate predictions over the range of measurements, if the data base is large. The difficulties of obtaining sufficient data samples with uncorrelated variables can however lead to doubts about the contribution of individual variables (and indeed whether some negatively correlated variables have been ignored entirely). When predictions for interrupted or congested traffic flow situations are required the number of possibly relevant variables increases considerably over the free flow case and it becomes virtually impossible to obtain enough measured data to establish the regression coefficients for all these variables. Most have to be ignored, leaving only those few variables that seem most significant from the measurements available. This must place limits on the strategies that can be developed to control noise.

A computer simulation technique offers the possibility of including as many variables as might seem relevant, rapid evaluation of any required flow cases, using current data or any possible future variations of that data.

The difficulties in this case are to obtain sufficient statistical data on the distribution of the values of the variables, and to place a suitable limit on the degree of realism incorporated in the simulation of the dynamic process. Absolute realism would, of course, be an impossible target, and so the simulation must be limited to a level that will give results suitable for the purposes to which they are to be put, e.g. overtaking behaviour may be an important factor in a traffic management problem, but initially, at least, it may be ignored when noise level over a long period is the desired result.

2.0 THE SIMULATION

This traffic noise simulation, using Fortran computer language is basically in two parts (i) the traffic mix and flow simulations, and (ii) the noise model.

The interrupted flow case can be broken down into four elements (a) Free Flow, (b) Decelerating Flow, (c) Idling, and (d) Accelerating Flow.

2.1 Free Flow

The free flow case gives a reasonably simple introduction to the technique. The 'periodic scanning' approach is used with a scanning interval of 0.25 secs, since the traffic simulation tends to go unstable if the interval is greater than 1.0 secs.

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Vehicles enter the simulation at a distance of -480m from the intersection 'stop line', using a random arrival headway, based on the 'shifted negative exponential' technique. The type of vehicle, light, medium or heavy, is obtained by random selection from a range 0 - 1.0 divided into the desired proportions of light, medium and heavy vehicles (i.e. 0 -0.1 for 10% heavy, 0.1 - 0.3 for 20% medium). The 'length' of the vehicle, including a minimum gap to avoid queue bunching, is taken from the mean of a large group of each class of vehicle. Since the random headway will not generally coincide with the 'scan' interval the actual vehicle 'arrival' locations is estimated from the time difference. The speed V_i at which a vehicle enters the system is related to its 'desired' speed V_d and the headway, ti,

$$V_i = V_d \left(1 - e^{-cti}\right) \qquad (a)$$

where V_d is taken randomly from a normal distribution curve having the specified stream mean speed $\bar{V}$ and a standard deviation of $\bar{V}/5$. Similarly, the initial acceleration a_i is related to the maximum acceleration for the vehicle class a_m (obtained from a large sample of published road tests)

$$a_i = a_m \left(1 - \frac{V_i}{V_d}\right) \qquad (b)$$

These conditions enable the initial noise level from the vehicle to the established using the curves for each vehicle class as a function of speed, from Nelson and Piner (1), and a correction of acceleration from Ringheim and Storeheire(2). This data is then stored and the next 'scan' made.

The new speed and location of the vehicles in the system are calculated from the previous 'scan' data, but once in the system the vehicle acceleration is governed by the 'generalised car-following theory', unless the 'gap' to the vehicle ahead is greater than 50m (when the initial acceleration equation is used). The generalised theory makes the acceleration a function of the leading vehicles speed V_n, the closing speed $(V_n - V_{n1})$ and the spacing $(X_n - X_{n+1})$

$$a_{n+1} = K \left[\frac{V_{n+1}}{X_n - X_{n+1}}\right]^P \frac{(V_{n-} V_{n+1})}{(X_n - X_{n+1})2} \qquad (c)$$

At each 'scan' the position and condition of each vehicle in the system is computed and the noise level at the observation location estimated using a decay rate of 20 Log $\frac{d}{do}$ for open hard surfaces, as suggested by Nelson (1). The programme goes on introducing vehicles to the system for the specified sample period (generally 600 secs). It is statistically preferable to average a number of short samples rather than use one long sample.

Noise levels are sampled at 1.0 secs intervals using energy additon of the contributions from all the vehicles in the system, but sampling does not start until the road section, $\pm$ 480m, is full of vehicles. From the noise history the units L_{10}, L_{50}, L_{90} are calculated from the cumulative distribution and L_{eq} from the summation of the 1.0sec values. Since a biased random sampling technique is used the actual traffic volume flow, percentages of vehicles by class, and average speed, will not be exactly as specified as must be computed for each completed example.

2.2 Braking, Idling and Acceleration

Olson and Rothey (3) have established distributions for the distances from the stop-line at which various fractions of the driving population start to brake when the amber signal appears. In the present programme a random fractional number (0 - 1.0) is generated for each vehicle approaching the light and it then 'goes' or 'stops' according to the population fractional value and distance and speed, in accordance with the data in (3). Once a vehicle has to stop the programme inserts an imaginary stationary vehicle at the stop-line and the stopping car obeys a slightly modified 'car-following theory' with maximum deccelerations limited to $-5\ m/s^2$. When the vehicle has reached its queue position, i.e. a vehicle 'length' behind that in front, it is assumed to be stationary, even though the previous 'scan' may indicate some small residual speed.

Some controlled tests indicate that at low decelerations there is a small reduction in noise, but at higher values the noise may increase. This has been incorporated in the model as -2dBA for decelerations in the range $0 - -3\ m/s^2$ rising to 1dBA at $-5 m/s^2$.

The idling noise from vehicles in the queue, while the red signal is operating, is taken from (1).

When the light changes to green there is a 1.25 sec delay before the vehicles accelerate away in accordance with Equation (a), if at the head of the queue or more than 50m from the vehicle ahead, otherwise using 'car-following theory' as in Equation (c). The appropriate noise increments for speed and accelerations are added as before.

The noise levels for every vehicle in the system, up to four lanes in each arm of a simple intersection, are summed for each 1 sec noise sample interval. At present right and left turning traffic is assumed to be simply additive to the traffic in the cross-flow, no simulation of these manoeuvres is attempted.

3. RESULTS

3.1 Free Flow

As a check on the basic data the simple free flow simulations results have been compared with values of L_{10} estimated using the 'Calculations of Road Traffic Noise'(4) method. Only 2 classes of vehicle were used in this case. Figure 1 shows the correlation between the 'simulations' and 'calculations', the latter being derived by regression analysis of measured data. Good agreement is evident for a wide range of conditions, flows from 200 to 900 vehicles/hr., % heavies from 10 to 45% and speeds from 20 to 72 km/hr, but at a fixed distance of 10m. Using three vehicle classes in the simulation shows no appreciable change in the correlations.

The general agreement between the two methods is sufficient to give confidence in the basic data for the intersection simulation case.

3.2 Interrupted Flow

Figure 2 shows a typical noise history for the interrupted flow case, with a traffic light cycle of 120 secs and the observer at the stop-line and 10m from nearest lane.

Preliminary results show that at this location the increment in L_{10} compared with the 'Calculation of Road Traffic Noise' free flow value is around 3.5 dBA. This is in good agreement with the value of 3.2 dBA obtained by regression analysis of measured data by Jones (5).

3.3 Measurements

Measurements have been made at a number of intersections using multiple simultaneous level recordings of noise and video tape records of traffic flow. These are currently being analysed to check the simulation data.

4.0 CONCLUSIONS

The simulation technique offers the ability to examine the effects of parameter variations in a controlled way, which is very difficult to achieve in a measurement situation. The current method gives results that are in good agreement with the 'standard' free flow prediction method derived from measurements. This suggests that the base data is good and that reliable interrupted flow noise levels should be obtained.

5.0 REFERENCES

(1) Nelson P., & Piner R., TRRL Report 752 1977. "Classifying Road Vehicles for the Prediction of Road Traffic Noise".
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(4) Dept. of Environment. HMSO 1975 "Calculation of Road Traffic Noise".
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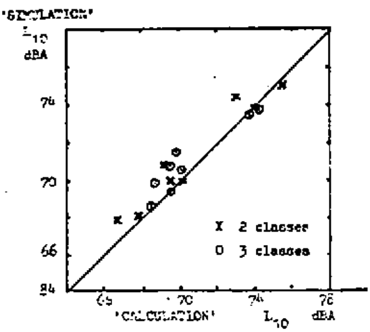

Fig. 1. CORRELATION BETWEEN 'CALCULATION' & 'SIMULATION' FREE FLOW METHODS.

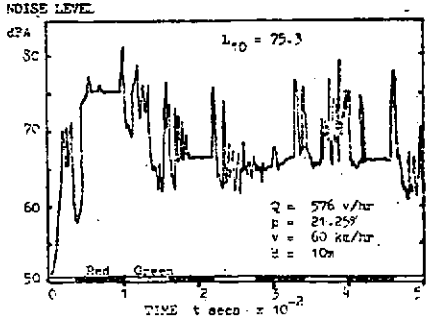

Fig. 2. SIMULATED NOISE HISTORY INTERRUPTED FLOW.