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NOISE AND URBAN TRAFFIC (INTERRUPTED FLOW)

D. GILBERT, L. MOORE AND S. SIMPSON

TRANSPORT SECTION, IMPERIAL COLLEGE, LONDON

The DoE memorandum 'Calculation of Road Traffic Noise'(1) describes a set of procedures for calculating L_{10} noise levels associated with road traffic. The memorandum sets out a method for predicting noise levels at a distance from a highway, which takes into account different traffic flows, composition and speeds, road configuration, intervening ground cover and the built form. In deriving this prediction method, account had been taken of existing prediction methods together with published and unpublished data from a wide variety of sources.

The aim of the memorandum was to permit prediction in as many cases as possible - covering both free and non-free traffic. But it was recognised that the method was not appropriate in certain complex traffic and layout situations. In particular, in situations where there are confined layout characteristics and/or considerable traffic congestion. Over the past ten years various studies of noise levels associated with interrupted flow traffic have been undertaken at Imperial College. These studies have confirmed that L_{10} levels in interrupted flow situations can differ from those in the free flow situation. In particular the levels are somewhat higher than would be predicted by the DoE memorandum.

In 1974-76 two studies of L_{10} noise levels associated with interrupted flow traffic (2) were undertaken. In the first of these the L_{10} equation was based upon data collected in a wide range of urban streets in Edinburgh and elsewhere. In all, some 300 sites were surveyed. Kerbside noise levels were obtained using Dawe sound level meters, and analysis was based on meter readings taken from time lapse film at 4 second intervals. A number of traffic variables were recorded including volume, composition (two categories), speed and pattern of arrival, along with layout characteristics. The equation, which evolved from a series of multiple regression (stepwise) analyses, was:

$$L_{10} = 55.7 + 9.18 \log Q(1 + .09H) - 4.20 \log Vy + 2.31T \qquad (1)$$

$R = 0.82$

S.E. = 2.7 dBA

where Q = traffic volume (vph)
H = proportion of vehicles over 1500kg(%)
V = mean speed of traffic (Km/h)
y = carriage width (m)
T = pattern of arrival

A more elaborate survey was then undertaken of 134 sites in the Sheffield/Rotherham area. Traffic, land use and layout characteristics were measured at each site, and data on noise levels was collected using more sophisticated equipment (Bruel and Kjaer sound level meters and Uher tape recorders - with subsequent analysis by Bruel and Kjaer pen recorder and statistical analyser).

Survey technique was broadly the same as that used in the first study, except that sound level meters were placed at the building line rather than at kerb-side. The predictive equation which evolved from the analysis of the data was:

$$L_{10} = 48.5 + 10.52 \log Q(1 + .04H) - 5.74 \log(dk + .5y) + 2.38 \log G \qquad (2)$$

$R = .83$

S.E.E. = 2.91

where dk = distance from survey point to kerb (m)
G = gradient (%) or 1, whichever is the greater

Equation (2) produced no significant improvement over the original, even though more sophisticated noise equipment had been used. Both the speed and pattern of arrival terms were found to be not significant in the second study, but distance from kerb and gradient have entered the equation. The form of the volume/composition term in both equations was broadly similar, and thus it might be assumed that the form of the relationship, as described by the equations, is broadly correct, though Equation (2) gives less weight to HCVs.

The surveys in these two studies covered a wide range of traffic and layout characteristics. It was concluded that the large standard errors of equations (1) and (2) might be explained in terms of:

a) fluctuations associated with noise characteristics of individual vehicles or drivers;
b) variations of the composition of that part of the traffic flow designated in previous studies as "heavy goods vehicles";
c) variation in one or more of the traffic characteristics such as speed, "acceleration noise", or level of service;
d) variations in layout and geometric characteristics.

It was apparent that fresh surveys of noise levels and traffic and layout characteristics would be required to gain a fuller understanding of the sources of the predictive error of the two equations. In the first stage of this new study layout variables were held within a narrow range to allow the influence of the other traffic variables on L_{10} levels to be examined. In the second stage of this study, the influence of a wide range of layout conditions was examined.

For the new study three vehicle categories were identified (3). A traffic logging apparatus consisting of pairs of belts containing photo-electric cells was used to measure speeds. The belts are fixed to the road surface and with their associated apparatus enable speed measurements to be made simultaneously on up to four traffic lanes. The speed distribution statistics of all vehicles passing the survey point were used to develop a level of service term which could be applied to see whether that factor explained any of the variation in L_{10} level. The range of layouts were constrained as follows: Carriageways were between 8 and 12 m in width; building layouts had continuous facades on both sides of the street; the distance from kerb to facade was not greater than 8m. Noise measurements were made 1m from the kerb at a height of 1.2m.

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Some 17 sites in West London were identified. Eight surveys were carried out at each site throughout the day to provide a range of traffic conditions. Each survey lasted 30 minutes. The surveys were undertaken with precision grade B & K equipment recorded on magnetic tape for subsequent analysis in the laboratory. The following equation was derived from the survey results:

$$L_{10} = 40.9 + 11.23 \log(Q + 8M + 12H) \quad (3)$$

$R = .94$

$S.E. = 1.17$

where Q = total traffic volume (vph)
M = medium heavy goods vehicles/hr.
H = heavy vehicles/hr

This equation statistically seems to represent a significant improvement over the earlier equations and it demonstrates the need for three composition categories. The introduction of mean speed and various measures of level of service did not result in any improvement in the equation.

In the second stage of this new study a new series of 30 minute surveys were carried out to investigate the effect of layout on geometry. Two main sets of surveys were carried out, these were: 165 surveys at sites with a wide range of layouts to estimate the effect of layout on kerbside levels; a further 120 surveys at these same sites but varying the distance of the microphone from the kerb to determine the effects of attenuation and reflection. The variables recorded included traffic volume and composition, carriageway width, distance from near and far facade to kerb, building heights, distance from junctions etc.

The first set of layout surveys consisted of approximately 165 surveys. Equation (4) below was the most satisfactory prediction equation arising from the comprehensive set of regression analyses undertaken. The function $11.23\log[Q + 8M + 12H]$ was included to conform to equation (3).

$$L_{10} = 43.32 + 0.982 [11.23\log(Q + 8M + 12H)] - 0.43CW + 2.72/FCN \quad (4)$$

$R = 0.94$

$S.E. = 1.22$

where CW = Carriageway width (m)
FCN = Distance from nearside kerb to nearside facade (m)

Variables such as distance to farside facade, building height etc., were found to have no significant effect. The term involving (FCN) can be interpreted as a proxy variable for reflection effects.

The final sets of regression analyses attempted to take into account the various reflection and attenuation effects that occur in urban streets. Reflection and attenuation variables were derived from the data and combined both practical and theoretical considerations. The object of the exercise was to construct a regression equation of the form:

$$L_{10} = a_0 + a_1 [11.23\log(Q + 8M + 12H)] + a_2 x_2 + a_3 x_3 \ldots\ldots\ldots\ldots a_r x_r \quad (5)$$

where $x_2, x_3, \ldots\ldots x_r$ = reflection and attenuation variables

$a_0, a_1, \ldots\ldots a_r$ = regression constants

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The reflection and attenuation variables were formulated relative to a reference position 1m from the kerb; they assumed that the effective noise source was located 3.5m from the kerb. The most significant variables were found to be:

$$\text{attenuation (A)} = \left\{\frac{d_k + 3.5}{4.5}\right\}^{\delta}$$

$$\text{reflection (R)} = 1 + \left\{\frac{(d_k + 3.5)}{(d_k + 3.5) + 2(FCN - d_k)}\right\}^{\delta'}$$

where d_k and FCN are as defined above.
δ is the ground cover index for propogation between source and receiver.
δ' is the ground cover index for propogation between receiver and facade.

typically δ, δ' are in the range 1 to 1.5.

Two further equations were developed. The first (6) based on 165 surveys incorporated reflection effects only, and applies when noise measurements were made at kerbside (d_k = 1m). The second (7) based on 120 surveys includes both reflection and attenuation effects and applies when the measurement position (d_k) varies.

$$L_{10} = 42.54 + 11.23\log(Q + 8M + 12H) - 0{,}423Cw + 6.46\log R \qquad (6)$$
$R = 0.95 \quad S.E. = 1.24$

$$L_{10} = 43.51 + 11{,}23\log(Q + 8M + 12H) - 0.423Cw + 4.55\log R - 10.21\log A \qquad (7)$$
$R = 0.94 \quad S.E. = 1.24$

A check was made on these last two models by using an independent data set based on noise surveys at 71 entirely different sites. For equation (7) the mean value and standard deviation of the residuals was +0.6 dB(A) and 1.33 dB(A) respectively. These results tend to confirm the adequacy of equation (7) in predicting L_{10} levels at any distance from the kerb for a variety of layout of urban streets.

It is considered that equations (3) or (4),(6) and (7) together comprise a valid prediction method. Equation (6) is preferable to equation (7) if the noise level is required at 1m from the kerb, since it possesses the lower standard error of estimate. All four equations suggest that a three way classification of vehicles is useful for noise prediction purposes and that, in urban streets, speed and level of service may not be significant factors affecting noise level. Because of the general nature of urban streets, changes in street layout will have relatively small effects on attenuation and reflection. However, the prediction equations described here will generally give higher and more realistic estimates of L_{10} levels in urban streets than the method set out in 'Calculation of Road Traffic Noise'.

REFERENCES

1. DEPARTMENT OF THE ENVIRONMENT 1975 HMSO. 'Calculation of Road Traffic Noise'

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