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A COMPUTER MODEL FOR DETERMINING THE TEMPORAL DISTRIBUTION OF NOISE FROM ROAD TRAFFIC

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ABSTRACT

A new method is described for computing the temporal distribution of noise from freely flowing traffic, which is much faster than Monte Carlo models of similar sophistication. Validation studies indicate that the standard deviation of the observed values from the computed values of L_{10}, L_{50} and L_{90} are 1.1, 1.3 and 1.9 dBA respectively.

Using the model, simple equations have been derived relating L_{10}, L_{50} and L_{90} to the traffic flow, mean speed, proportion of lorries in the traffic stream and the distance from the roadway where the propagation is over grassland. The equations are designed primarily for traffic conditions beyond the range of applicability of existing prediction schemes yet are consistent with the conditions encountered in the majority of urban roadway networks.

The computer model can be readily extended to synthesize traffic noise in urban roadway networks and, in principle, noise from different transport modes. It is intended to develop the modelling technique further to construct an urban noise model incorporating complex roadway networks and ultimately various transport modes.

1. INTRODUCTION

Transport noise and, in particular, road traffic noise features prominently among the environmental disadvantages of urban areas. Both the pervasivity of traffic noise and public awareness of its detrimental effects are increasing and at the present time the demand for traffic noise control is acute. A practical approach to the control of traffic noise was outlined in a report by the Urban Motorways Committee.[1] The report advocates the planning of new development to reduce the disturbance caused by traffic noise and the provision of sound insulation rights to protect properties badly effected. In order to implement these measures effectively those involved in planning and design must be in a position to predict accurately appropriate traffic noise units for a wide range of urban conditions.

For practical design purposes a single figure measure of traffic noise annoyance is desirable. Sociological studies of the effects of traffic noise indicate that noise units incorporating a measure of the variability in noise level correlate well with expressed annoyance.[2,3] The researchers, however, are not agreed on the precise form of the variability unit and, further, the effects of control measures on the variability of the noise cannot yet be estimated accurately.

Existing prediction techniques almost invariably attempt to predict much simpler indices such as L_{10}, the noise level exceeded for 10% of the time, and even these are confined to relatively simple situations.[4, 5, 6] The L_{10} level, averaged over the period 0600 to 2400 hours, correlates reasonably well with noise annoyance.[6] Consequently the exigencies of traffic planning and the current availability of the simple prediction techniques for L_{10} have prompted both the Noise Advisory Council and the Urban Motorways Committee[1] to recommend, in the absence of further guidance, the adoption of the 18 hour L_{10} index for planning purposes. The problems remain to extend the present L_{10} prediction techniques to complex situations and to develop prediction methods generally for the more meaningful noise annoyance indices.

Three approaches have been used in developing prediction schemes for traffic noise. These are

(1) Field measurement techniques,[6, 7, 8]

(2) Scale model techniques[9] and

(3) Theoretical models[10]

Field measurements provide the closest contact with reality and are obviously attractive. However, the experimenter has little control over the parameters affecting the noise level and interactions between the various parameters cannot be readily separated. Scale model techniques enable the experimenter to control road and building layout but considerable initial research is needed to model the acoustic properties of real surfaces. Furthermore in scale models absolute noise levels cannot be determined and at present the acoustic characteristics of moving traffic have not been simulated. Calculations based on theoretical models are more economic than the other techniques and allow situations to be studied beyond the range of those readily observable. However, existing computer models which use Monte Carlo methods to generate large numbers of vehicles representing heavy traffic have proved to be unwieldy requiring the use of large computers to minimise computer time.

At the Transport and Road Research Laboratory a computer program has been developed for predicting the cumulative time level distribution generated from road traffic. The model uses a new principal of synthesis, contains the desired flexibility for synthesizing noise from complex roadway networks and is much faster than previous models of similar sophistication. This report describes the philosophy of the model and compares its predictions with empirical data and with other predictive methods.

2. THE BASIC PRINCIPLES

The theory underlying the synthesis calculation can be most conveniently described for the simplest case of a single lane roadway and of traffic consisting of acoustically identical vehicles each travelling with an equal and constant speed. The extension to non-identical vehicle categories and multi-lane roadways is considered in subsequent sections.

The hypothetical roadway element, AB shown in figure 1, extends symmetrically to both sides of the observation point 0. The total length of roadway, AB, considered to contain traffic contributing to the observed noise levels at 0 is defined such that

$$\frac{AB}{2} = 500S \text{ metres}$$

where S km/hour is the mean speed of a vehicle travelling along the roadway. Each vehicle therefore takes exactly 1 hour to travel from A to B. If the level, L_R, in dB(A) emitted by the moving vehicle measured at some reference distance, R metres, is known and if the vehicle is assumed to travel so that the origin of noise at any instant is localised effectively at a point situated along the centre line of the road lane, then the maximum and minimum levels generated at 0 due solely to the noise transmitted by the vehicle are given by,

$$L_{max} = L_R + 10F \log_{10} R - 10F \log_{10} (d + w/2)$$

and

$$L_{min} = L_R + 10F \log_{10} R - 5F \log_{10}[(500S)^2 + (d + w/2)^2]$$

respectively, where F denotes the power index defining the attenuation of sound intensity with distance, eg F = 2 for hemispherical spreading from the source.

Between L_{min} and L_{max} a distribution of levels exists where the percentage time, t, that an observed level, L, is exceeded depends upon the total time the vehicle is at a distance $\leqslant \ell$ from 0 and is given by:

$$t\% = \frac{\ell(L)}{500S} \cdot \frac{100}{1} = \frac{\ell(L)}{5S} \quad \text{. . . . .} \quad (1)$$

$$\text{where } \ell(L) = \left\{ 10^{[(L_R - L)/5F + 2 \log_{10}R]} + (d + w/2)^2 \right\}^{½}$$

$$\text{and } \quad L_{min} \leqslant L \leqslant L_{max} \quad \text{. . . . .} \quad (2)$$

By substituting values of L into equation 1 a cumulative time-level distribution is obtained which effectively represents the noise distribution from a traffic flow of one vehicle per hour. If the assumption is made that this distribution represents the probability distribution for a flow of one vehicle per hour, distributions for flows of 2 or more vehicles per hour may then be derived by combining the single vehicle distribution with itself in a statistically correct fashion. Such a combination procedure was described and validated in a previous paper.[11] The initial assumption that the calculated single vehicle distribution is appropriate to a flow of 1 vehicle per hour is inaccurate since it assumes an even flow of vehicles and also assumes that at any point all the noise received comes only from the nearest vehicle. This must mean that the derived L_{min} values of the single vehicle distribution are about 3dB(A) less than they should be and also that the probability cut off at the peak value, L_{max}, is gradual rather than abrupt. Nevertheless these assumptions make little difference at realistic flow levels since in the combination process the vehicle are added quite randomly and at flows of about 10 vph the distribution is representative of a completely random flow.

The combination technique has been used, therefore, to combine the single vehicle distribution obtained from equation 1 to obtain a series of cumulative time-level distributions corresponding to a range of traffic flows. Since the flow is doubled each time identical distributions are combined, realistic traffic flow situations are achieved after only a few combination calculations. For instance eleven combinations are required to generate a flow of 1024 vehicules per hour, ie 2^{10} vehicles, and of course since any number can be expressed as a binary expansion the level for any flow could be generated by combining the level distributions associated with the binary powers in the expansion of the flow number. It was suspected, however, that such particular vehicle flow predictions would seldom be required in practice and the computer program is designed to provide a range of possible situations by generating hourly distributions and noise indices in intervals of 200 vehicles per hour. This is considered to be sufficiently detailed to permit accurate interpolations if intermediate values are required.

3. APPLYING THE MODELLING TECHNIQUE TO REALISTIC TRAFFIC SITUATIONS

So far the theoretical principles underlying the method of synthesis have been described assuming that all vehicles can be generalised into one group with identical noise emission and performance and that the reference level L_R, speed S and the power index F in equation 1 are known for this vehicle group. In practice traffic does not consist of a series of acoustically identical sources and the different classes of vehicle travel at different mean speeds within the traffic stream. Furthermore the concept of a single lane roadway is unrealistic and in a realistic model must be extended to cover the various multiple lane configurations met with in practice. In these cases provision must be made to allow a variation in the number of vehicles occupying each lane and also to allow for the different proportions vehicle categories in each lane.

3.1 Categories of noise sources

The acoustic classification of vehicle types has been considered by various workers, notably by Ross[12] and Lewis.[13] Both agreed that, with respect to noise generation, vehicles can be broadly classified into two groups. The first group can be described as 'cars' and consists almost entirely of petrol fuelled vehicles having the general operating characteristics of passenger cars. The second group covers all vehicles exceeding 30 cwt. This group may be referred to as 'lorries'. It was further agreed that over the normal operating range and under free flow conditions the increase in peak noise generation was linear with the logarithm of increasing vehicle speed, the increase amounting to about 9 dB(A) per doubling of speed. However, although the magnitudes of the regressed levels obtained for the lorry group by both authors were virtually identical, the regressed car levels obtained by Ross were 3 to 4 dB(A) lower than the corresponding levels obtained by Lewis, even when due account was taken of the different measurement configurations. It seems likely that these differences arise partly because of the relatively small car sample studied by Ross and partly because the majority of the drive-by tests were carried out in vehicles driven over a smooth fine asphalt surface on a test track whereas Lewis's measurements relate to vehicles driven on public roads, presumably with either a hot rolled asphalt surfacing or a surface dressing.

Subsequent research has indicated that at high speeds the peak levels obtained on fine asphalt may be on average 3 dB(A) lower than those obtained from identical tests carried out on coarser surfaces such as hot rolled asphalt or surface dressing that are typical of motorways and major roads. Consequently the level-speed regression lines obtained by Lewis, normalised to 7.5 metres distance and adjusted for a microphone height of 1.2 metres, were used in the model. These graphs are reproduced in figure 2.

In order to distinguish between the different vehicle categories in the noise model both the mean speed of the vehicle group, S, and the corresponding reference level, L_R, obtained from figure 2 are first substituted into equation (1) to generate the single vehicle cumulative time-level distribution for each group. Then, given the estimated percentage cars to lorries in the projected traffic stream, these distributions are combined and normalised in the desired proportions to obtain an equivalent single vehicle distribution. The noise distributions corresponding to progressively higher traffic flows are then obtained, as before, by successively combining the equivalent single vehicle distribution.

3.2 Multi-lane Roadways

Having established a method for simulating noise from traffic flowing on a single lane consisting of both cars and lorries travelling at different mean speeds, the extension to multi-lane roadways is straight forward. Firstly, for each lane, the single vehicle distribution is derived, as described in the previous section, taking into account composition differences in each lane. Next, the equivalent single vehicle cumulative time/level distribution is obtained by combining the single vehicle distributions derived for each lane. Finally the equivalent single vehicle distribution is combined successively to obtain a series of distributions appropriate to a range of traffic flows.

4. PROPAGATION OVER DIFFERENT SURFACES

Before the simulation technique can be tested against real situations there remains the problem of determining the power index F in equation (1).

Several experimental studies of sound propagation over absorbent surfaces have been reported.[14, 15, 16] It has been established that the attenuation of sound level with distance from a point source is in excess of that due to air absorption and the inverse square law of spherical spreading and is highly frequency dependent.

Generally traffic noise is not frequency analysed as this introduces additional complications into the measurement and analysis, which appear to be of little value in assessing subjective dissatisfaction with traffic noise. Consequently to calculate the single vehicle pass by characteristics defined by equation (1) it is sufficient to determine the attenuation with distance of noise from a typical vehicle source for each type of surface likely to be encountered in practice. A series of such experiments were therefore carried out over three types of surface typifying (a) a hard reflecting surface (b) mown grass and (c) an absorbant surface typical of common land or rough grassland. The noise source was a Landrover fitted with a hand throttle which allowed the engine speed to be regulated and maintained constant for short intervals. Figure 3 shows the A-weighted, 1/3 octave noise spectra for the Landrover and for various other vehicles measured at a fixed reference distance of 7.5 metres. When each spectrum is normalised at 1000 Hz, as shown in figure 3, it can be seen that each spectrum has essentially the same profile and the differences between the Landrover and the other vehicle categories are not significant even though the range in vehicle capacity is considerable. It can be concluded, therefore, that the Landrover is a typical vehicle noise source. The levels emitted by the Landrover engine were measured using standard equipment at a reference position situated 7.5 metres from the centre of the engine and simultaneously at various other distances up to 100 metres from the engine centre. Several repeat measurements were made at each distance and an average value of the mean peak level was estimated. The microphone heights were 1.2 metres above the ground surface and all measurements were made in dry and calm conditions. The attenuation, dB(A), with distance profiles obtained are shown in Figure 4 for the three surfaces studied. It can be seen that although each set of measurements exhibit a noticeably sinusoidal variation about the mean line which is due to complex interference effects at discrete frequencies, a single line characteristic is sufficient to specify the sound attenuation within 1 dB at any distance up to 100 metres from the source. The single line profiles were therefore used to calculate the values of F in equation (1) for the different surfaces studied. These values, appropriate to each surface, are also included on the diagram.

5. VALIDATION OF THE MODEL

The model has been tested by comparing model predictions with measurements in simple one road and free flow situations. To make this comparison the noise of traffic alongside various single carriageway roads carrying freely flowing traffic was measured. The sites were specially chosen so that the roadway was level for at least 150 metres either side of the observation point and the surrounding land was free from obstacles to the sound path. Measurements were made of flow, numbers of vehicles over 30 cwt and the mean speed of each vehicle category in both lanes of the roadway. The recordings of traffic noise were analysed and presented as cumulative time/level distributions and the L_{10}, L_{50} and L_{90} levels were estimated.* A total of 21 measurements were made at 5 separate sites and two types of ground cover were included, short grass and rough grassland. The range of each variable covered by the field data was as follows:

Flow, Q, = 300 to 2000 veh/h

Speed, V, = 50 to 90 km/h

% lorries, p, = 6 to 50 per cent

distance from the roadway, d = 5 to 100 metres

(It should be noted that the minima and maxima of the traffic parameters did not coincide, the distribution in three dimensional space being ellipsoidal rather than rectangular). The traffic and roadway data obtained at each site were input to the computer program and the predicted values of L_{10}, L_{50}, L_{90} and the noise climate ($L_{10} - L_{90}$) compared with the measured values. The results are shown in figures 5, 6, 7 and 8. A linear regression was carried out on each index to establish whether there was any systematic difference between observed and predicted values. The regression lines, included on each graph, indicate that except for the noise climate the predicted values are systematically greater than the observed values although for L_{10} the over-prediction tendency is barely noticeable. The origins of this effect are difficult to determine. However, the model does assume no physical interaction between vehicles moving in the traffic stream and each vehicle is assumed, at any time instant, to radiate noise along a sound path which is unobstructed by other vehicles in the traffic stream. Both these assumptions become invalid at high traffic flows and, qualitatively, both could give rise to systematic over-predictions of the various fractiles in the distribution.

The standard errors of the differences between observed and predicted L_{10}, L_{50}, L_{90} and $L_{10}-L_{90}$ are 1.1 dB(A), 1.3 dB(A), 1.9 dB(A) and 2.2 dB(A) respectively implying that for the worst case, the $L_{10}-L_{90}$ value, 95% of the predicted results would be within ± 4.4 dB(A) of the observed values. Clearly the standard error in the prediction of the noise climate is affected by the significantly larger error in determining the L_{90} index.

It is evident that the computer synthesis does provide a good prediction of the level distribution generated by freely flowing traffic and the systematic effects noticed are not sufficiently great to necessitate any alteration in the basic assumptions.

* The L_{50} and L_{90} indices are the levels exceeded for 50 per cent and 90 per cent of the time respectively

6. SIMPLE PREDICTIVE EQUATIONS

Although the model is quite efficient in its use of computer space many potential users will not have ready access to a digital computer and may prefer to use approximate equations derived from the digital computer program output. Equations of the form

$$L = \alpha + \beta \log_{10} V + \gamma \log_{10} Q + \delta p - \epsilon \log_{10} d \quad \ldots\ldots\ldots\ldots \quad (3)$$

where L is the noise level, V is the mean speed of the traffic, Q the vehicle flow, p the percentage lorries and d the distance of the observation point from the nearside kerb, have been suggested by other workers[8] or are implied in the graphical prediction schemes.[6] In the published equations the coefficients α to ϵ are given constant values. Detailed analysis of traffic noise data, however, clearly implies that over extensive ranges these coefficients are not constant but complex coefficients more precisely defined as functions of one or more of the dependent traffic parameters. This fact was observed by Delany in an unpublished study.

To examine in more detail the functional forms of the parametric coefficients an analysis was carried out using the traffic noise model to generate values of L_{10}, L_{50} and L_{90} for a wide range of hypothetical inputs.

A preliminary investigation of the output data suggested that, at a fixed reference distance of 10 metres from the roadway, the L_{10} index should be expressed by an equation of the form

$$L = \alpha(p) + \beta(p)\log_{10} V + \gamma(p)\log_{10} Q \quad \ldots\ldots\ldots\ldots \quad (4)$$

where α, β and γ are not constant but are functions of the percentage heavy goods vehicles, p, only and presumably reflect the dependence of L_{10} on the lorry peaks in the traffic stream. Alternatively it was found that both the L_{50} and L_{90} indices were better represented by an equation of the form,

$$L = \alpha(p,Q) + \beta(Q)\log_{10} V + \gamma(p)\log_{10} Q \quad \ldots\ldots\ldots\ldots \quad (5)$$

where β is now a function of the vehicle flow, Q, only and α is a function of both p and Q. This latter form reflects the stronger dependence the lower fractile indices have on the total number of vehicles in the traffic stream rather than the number of peaks produced by individually noisy vehicles. The α, β and γ functions were determined using standard numerical partial differentiation techniques and simple curve fitting. The functions obtained, chosen for their degree of simplicity and correlation with the data, are listed below for the case when propagation is over short grass.

for L_{10} $\alpha = 11.4 + 0.3p$

$\beta = 20.3 - 0.18p$

$\gamma = 8.0 + 0.06p$

for L_{50} $\alpha = 8.0 - 0.014Q + 0.4p$

$$\beta = 0.008Q$$

$$\gamma = 18.5 - 0.1p$$

and for L_{90} $\alpha = -11.5 - 0.007Q + 0.15p$

$$\beta = 0.003Q$$

$$\gamma = 24.0 - 0.03p$$

In addition to the computations made at the reference position values of L_{10}, L_{50} and L_{90} were calculated for various traffic speeds, flows and compositions at distances up to 100 m from the roadway. Again propagation was considered to be over grassland. The attenuation relative to the reference position is shown as a function of distance, d in figures 9, 10 and 11 for L_{10}, L_{50} and L_{90} respectively. The figures show that whilst the decay of L_{10} with distance from the road is virtually independent of the traffic speed, flow and composition and a single line characteristic is sufficient to specify the sound intensity at any distance up to 100 metres from the road the attenuation of both L_{50} and L_{90} depend markedly upon the vehicle flow, Q. The relationships found to fit the attenuation with distance data, again chosen for their functional simplicity and degree of correlation achieved are

$$(L_{10})_{att} = 16(1 - \log_{10}d)$$

$$(L_{50})_{att} = 10(\log_{10}Q - 2)(1 - \log_{10}d)$$

$$(L_{90})_{att} = 6.5(\log_{10}Q - 2.3)(1 - \log_{10}d)$$

By substituting the α, β and γ functions in equation 4 and 5 and combining the resulting expressions for L_{10}, L_{50} and L_{90} with the appropriate attenuation with distance functions the final form of the equations relating L_{10}, L_{50} and L_{90} with the flow, mean speed, composition of heavy vehicles and distance from the roadway are obtained.

$$L_{10} = 27.4 + 0.3p + (20.4 - 0.18p)\log_{10}V + (8.0 + 0.05p)\log_{10}Q - 16\log_{10}d \quad \ldots \quad (6)$$

$$L_{50} = 8.0 - 0.014Q + 0.4p + 0.008Q\log_{10}V + (18.5 - 0.1p)\log_{10}Q - 10(\log_{10}Q - 2)(\log_{10}d - 1) \quad \ldots \quad (7)$$

$$L_{90} = -11.5 - 0.007Q + 0.15p + 0.003Q\log_{10}V + (24.0 - 0.03p)\log_{10}Q - 6.5(\log_{10}Q - 2.3)(\log_{10}d - 1) \quad \ldots \quad (8)$$

7. VALIDATION OF THE PREDICTIVE EQUATIONS

7.1 Validation

Validation of the predictive equations was carried out by comparing predicted values of L_{10}, L_{50} and L_{90} with the corresponding measured values appropriate to propagation over short grass. As before, a linear regression was performed on each data set to establish systematic effects. It was found that the L_{50} and L_{90} predictive equations systematically over-predicted the measured values by a similar magnitude to that observed in the test of the model algorithm but no systematic effects were discovered for the L_{10} predictive equation. The standard errors of the differences between observed and predicted L_{10}, L_{50} and L_{90} were 0.8dB(A), 1.4dB(A) and 1.6dB(A) respectively. These errors are slightly less than those obtained previously when validating the computer model. This is to be expected since the standard errors in the model predictions were obtained using measured data where propagation was over two types of surface, short grass and rough grassland, whereas the predictive equations refer only to propagation over short grass.

7.2 Comparison of the Predictive Equations

The equations were compared with the empirical equations derived by Delany[8] using a variety of traffic and distance parameters within the ranges acceptable to both sets of equations. The ranges used were

Q = 700 to 2000 veh/hr

V = 50 to 90 km/hr

p = 10 to 50 per cent

d = 10 to 100 metres

The standard errors of the differences between L_{10}, L_{50} and L_{90} values was 0.6 dB(A), 1.0 dB(A) and 2.3 dB(A) respectively. The L_{10} predictive equation has also been compared with the predictive procedure described in the Department of the Environment's Design Bulletin 26[17] for the following range of parameters.

Q = 500 to 2000 veh/hr

V = 50 to 90 km/hr

p = 10 to 50 per cent

d = 15 to 100 metres

The standard error of the differences between the predicted values of L_{10} was 1.3 dB(A). A comparison of the L_{10} predictions given by the three techniques is given in figure 12. The figure shows that there is no evidence of systematic differences between L_{10} given by Delany[8] and equation 6 but there is some evidence that equation 6 gives an L_{10} slightly in excess of that given by the procedure in Design Bulletin 26.[17] However Design Bulletin 26 predicts that 18 hour L_{10} level at a building facade and part of the systematic difference may be attributable to a small error in the correction applied to the Design Bulletin level to reduce it to an hourly freefield L_{10} level. In any case since the standard errors in the observed differences are small it can be stated that all three methods are in good overall agreement for the ranges of parameters specified previously. This general agreement between the different techniques provides further evidence of the validity of the computer model.

Having established that the computer derived equations adequately predict L_{10}, L_{50} and L_{90} within the specified ranges it is possible to examine meaningfully the parmetric variation on noise level implicit in these expressions. Considering first the attenuation with distance functions, the slope of the L_{10} decay characteristic, given in figure 9, implies that L_{10} attenuates at a rate of 4.7 dB(A) per doubling of distance. This is in good agreement with the corresponding value derived by Delany of 4.4 dB(A) per double distance and is in fair agreement with the decay rate given in the Design Bulletin.

The L_{50} and L_{90} decay functions are not as easily compared. Delany's empirical equation gives only a single decay characteristic typical of the flows studied whereas the computer expressions clearly indicate that there is a range of decay profiles depending markedly upon the vehicle flow. Table 1 below compares and summarises the two approaches.

TABLE 1

Comparison of the rates of attenuation with distance given by different prediction techniques

Noise Index dB(A)	Decay Rate dB(A)/double distance			
	Design Bulletin 26 [17] Q = ⩾ 500 veh/h	Delany[8] Q = 700 – 4000 veh/h	Equation 6, 7, 8 Q = 200 veh/h	Q = 2000 veh/h
L_{10}	4.0	4.4	4.7	4.7
L_{50}	–	3.4	1.0	4.3
L_{90}	–	2.4	0.1	2.3

The table shows that the decay coefficients for the L_{50} and L_{90} indices are in fair agreement when the flow is high but in poor agreement at low flows.

Comparisons between the different methods have also been made for the various traffic parameters. Table 2 summarises and compares the increase in L_{10} when the speed and the flow of traffic doubles and Table 3 compares the increase in L_{10} when the percentage lorries increases by 40 per cent.

TABLE 2

Increase in L_{10} when the value of the traffic parameter is doubled

Traffic Parameters	Design Bulletin 26[17]	Delany[8]	Equation 7	
	p = 0–40%		p = 0%	p = 40%
V	6.0 dB(A)	4.9 dB(A)	6.1 dB(A)	4.3 dB(A)
Q	2.4 dB(A)	2.7 dB(A)	2.4 dB(A)	3.0 dB(A)

TABLE 3

Increase in L_{10} when the percentage of lorries increases by 40 per cent

Traffic Parameters	Design Bulletin 26[17]	Delany[8]	Equation 7		
	Q ⩾ 500 veh/h V = 50–100 km/h	Q = 700–4000 veh/h V = 50–100 km/h	Q veh/h	V km/h	Value dB(A)
p	4.0 dB(A)	4.7 dB(A)	200	100	2.2
			1000	100	3.6
			2000	100	4.2
			200	50	4.4
			1000	50	5.8
			2000	50	6.4

Tables 2 and 3 show that while both the empirical techniques specify a single L_{10} increment for a specified increase in each traffic parameter the computer derived expression gives rise to a significant range of L_{10} increments. It should be stressed, however, that the empirical expressions were derived from data obtained primarily alongside major roads where mean speeds and flows were predominantly high whereas the computer expression was purposely designed to encompass much lower traffic flows. It is not surprising, therefore to find that the parametric coefficients are generally in good agreement when both traffic speeds and flows are high, a fact also noted in the comparison of the decay coefficients.

8. FUTURE DEVELOPMENT OF THE NOISE MODEL

The principles of combining noise from separate time varying sources, that were developed in a previous study, have been used in the model described in the report to determine cumulative time/level distributions for multiple source situations given a typical noise level distribution for a single source. Although the model presently considers the separate noise sources to be road vehicles the technique could be applied, in principle, to other transport noise generators such as aircraft or trains. Furthermore, since the modelling technique is rapidly assimilated by the computer, the program could be developed to model noise arising from mixed transport modes or traffic noise from complex roadway networks without the disadvantages of a lengthy computation.

In the case of road traffic noise there are several advantages to be gained by using the full sophistication of the computer program rather than resorting to the simpler approach of using the regressed equations. Firstly, an equation provides only one point on the cumulative time/level distribution whereas the computer algorithm generates the whole distribution. This may be critically important if future development suggests that a new index incorporating different fractiles of the distribution should be adopted to rate the disturbance caused by traffic noise. Secondly the equations include only three dependent traffic parameters, flow, mean speed, and percentage of lorries and are only appropriate to propagation over short grass, whereas the computer model considers traffic in much more detail and provides the user with the facilities for varying such factors as the distribution of vehicles in multi-lane roadways, the speeds of the various vehicle categories, the average noise levels emitted by each vehicle category for a specified speed and the attenuation of noise propagating over surfaces other than short grass. These added facilities enable a wider range of traffic control policies to be studied such as the introduction of heavy vehicle lanes on motorways, speed restriction of vehicle categories and the effects on traffic noise of reducing the levels emitted from individual vehicle categories.

It is intended to develop a computer model to compute distributions of traffic noise at selected sites in urban roadway networks and ultimately to generate a comprehensive means of predicting urban transport noise by including noise from other transport modes.

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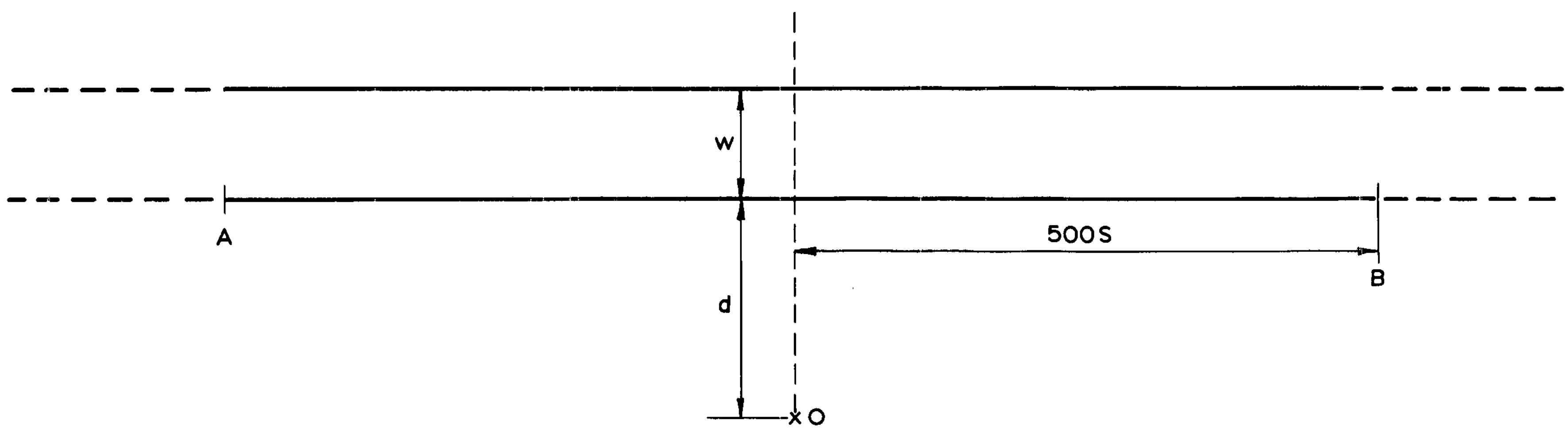

Fig. 1 PLAN OF THE HYPOTHETICAL SINGLE LANE ROADWAY ELEMENT

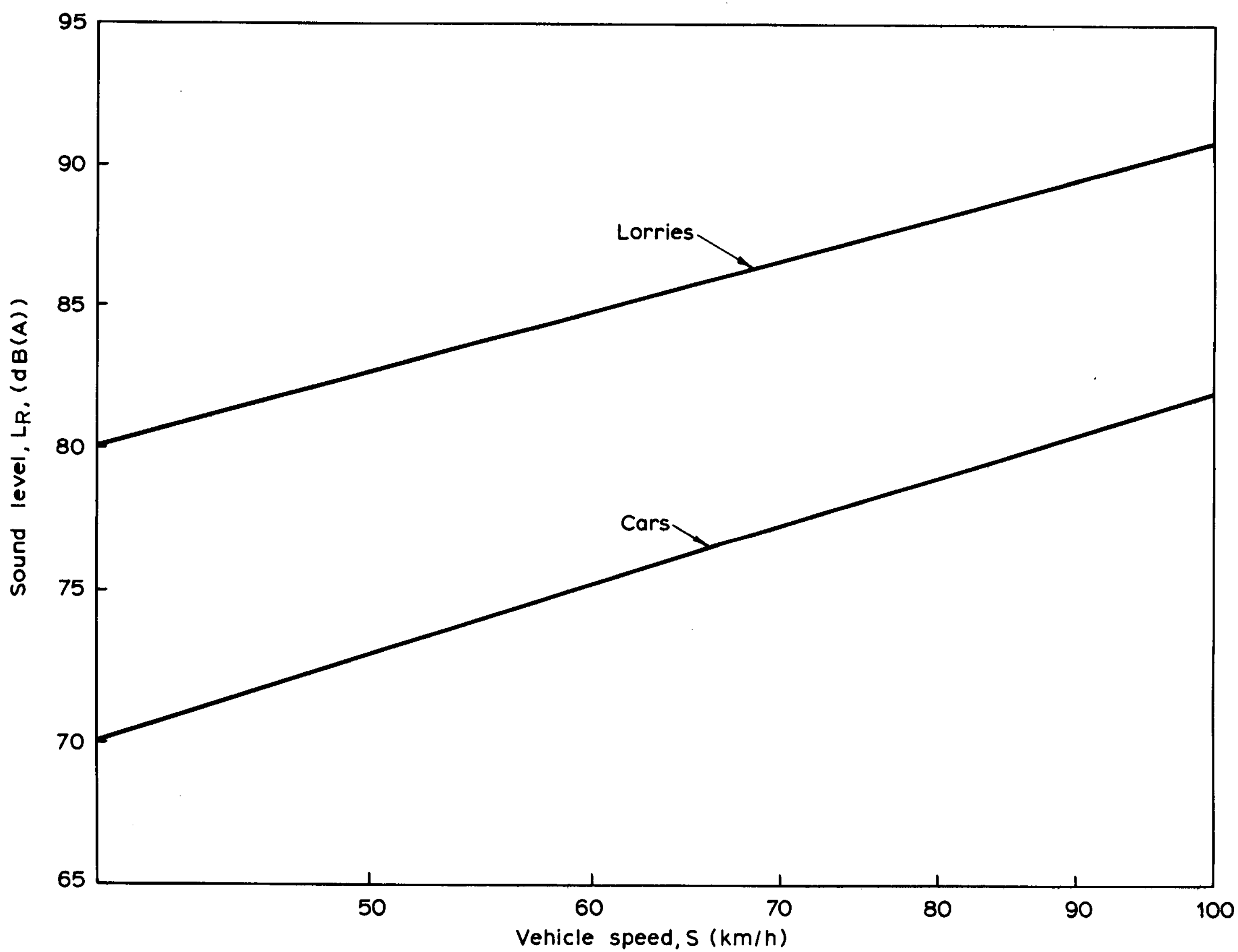

Fig. 2 LEVEL-SPEED RELATIONSHIPS FOR CARS AND LORRIES

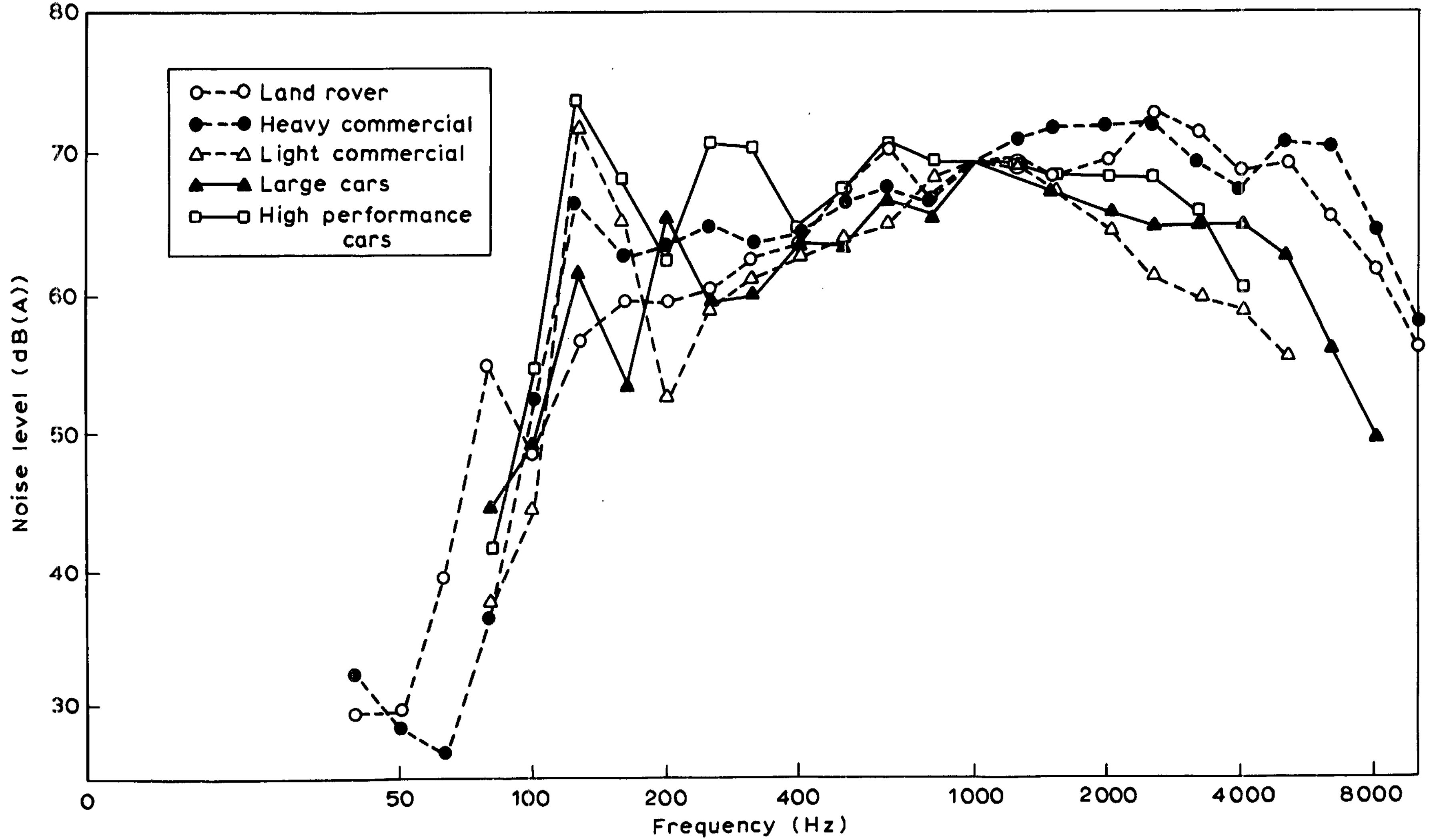

Fig. 3. TYPICAL VEHICLE NOISE SPECTRA NORMALISED AT 1000 Hz

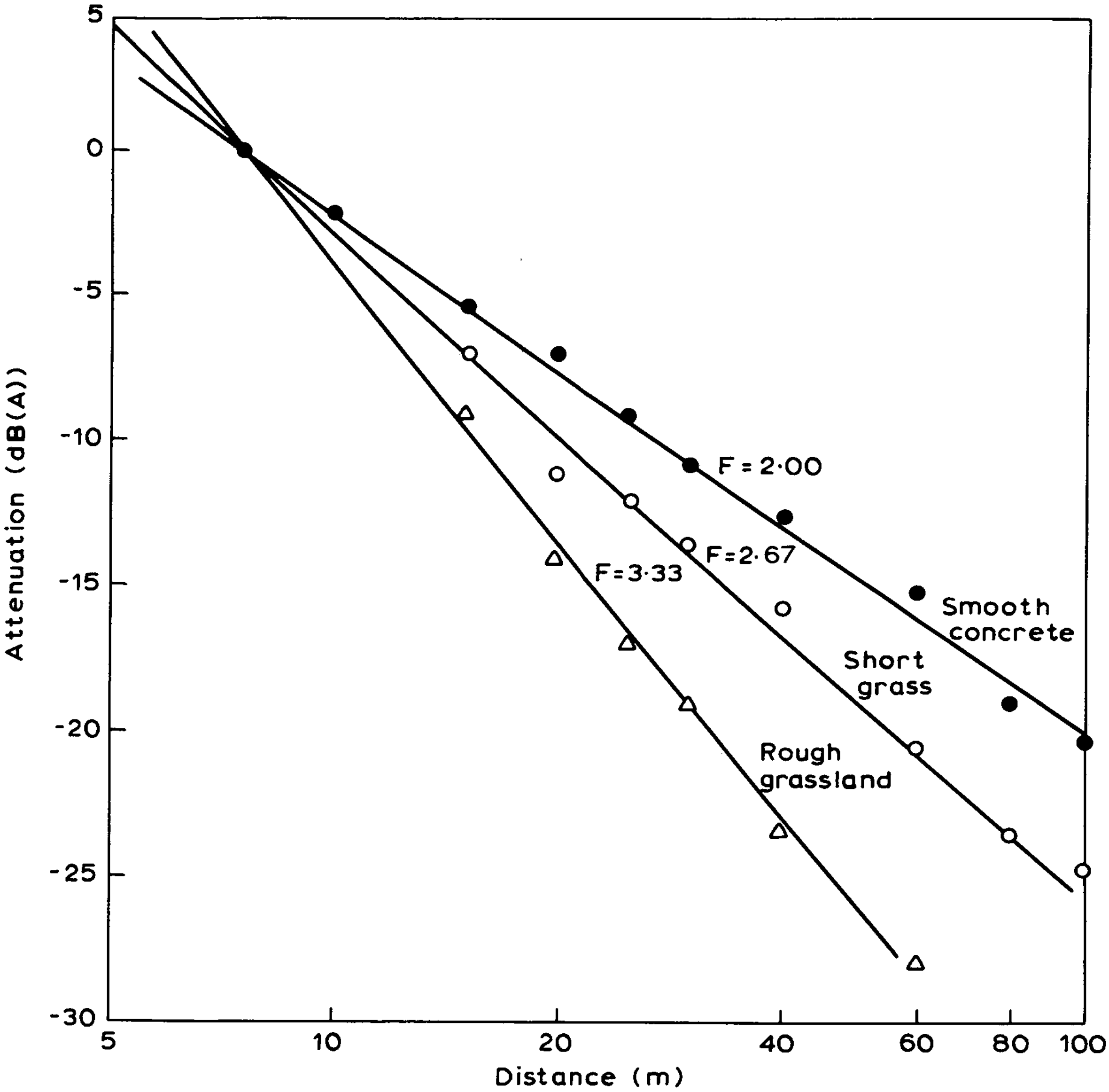

Fig. 4. ATTENUATION WITH DISTANCE CHARACTERISTICS FOR VARIOUS GROUND SURFACES

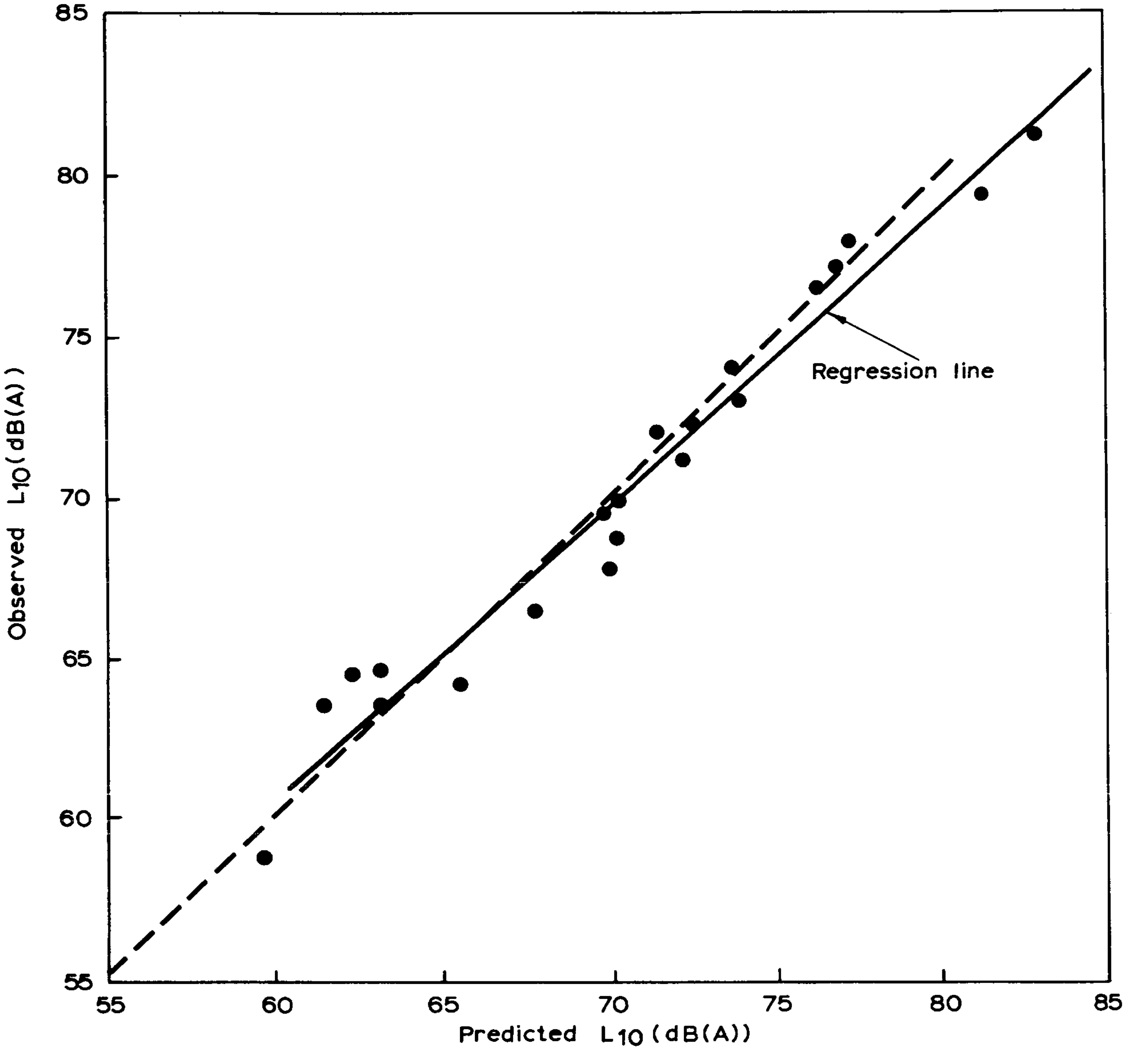

Fig. 5 COMPARISON OF OBSERVED AND PREDICTED L_{10} FOR SINGLE CARRIAGEWAY ROADS

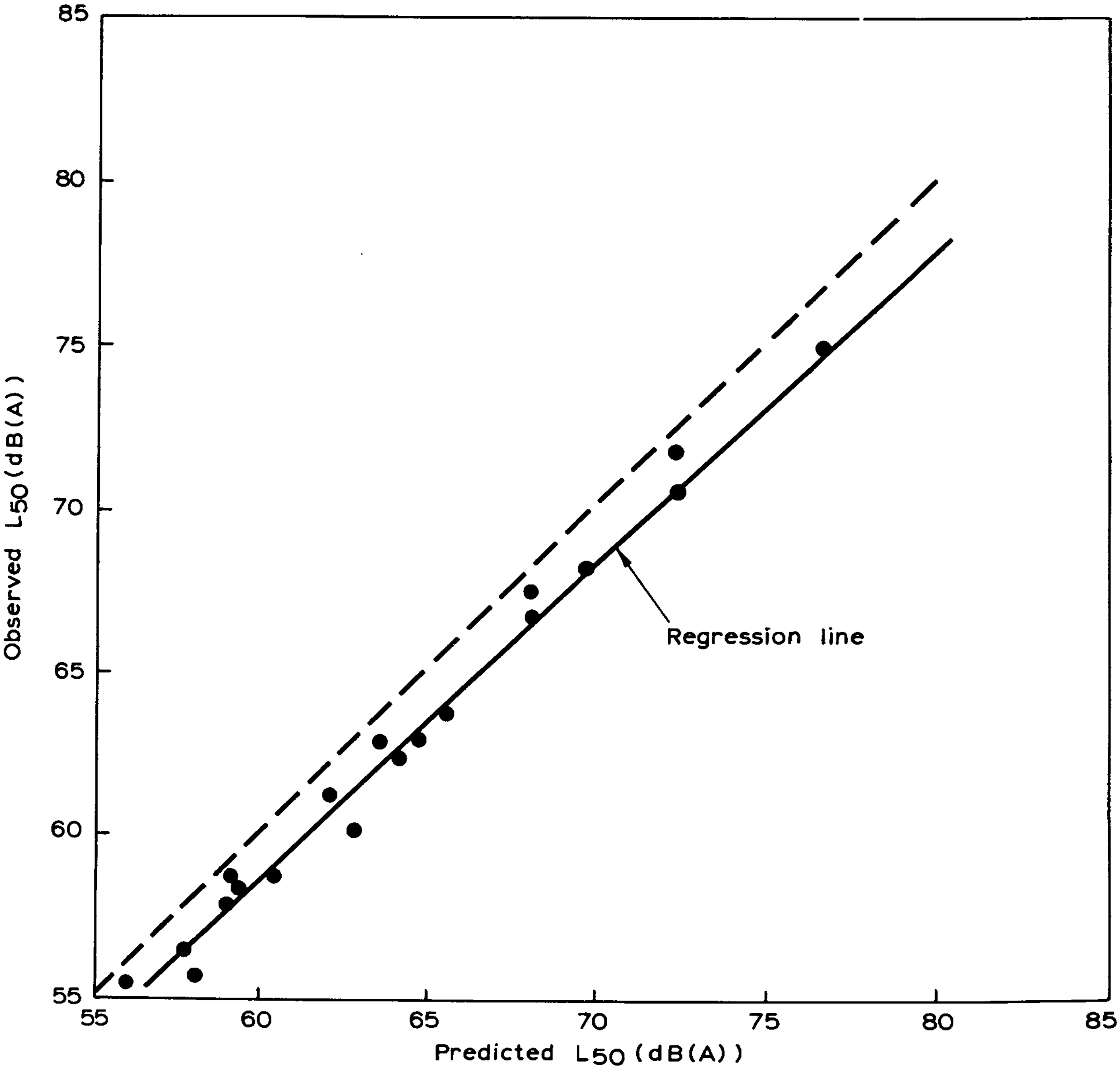

Fig. 6 COMPARISON OF OBSERVED AND PREDICTED L_{50} FOR SINGLE CARRIAGEWAY ROADS

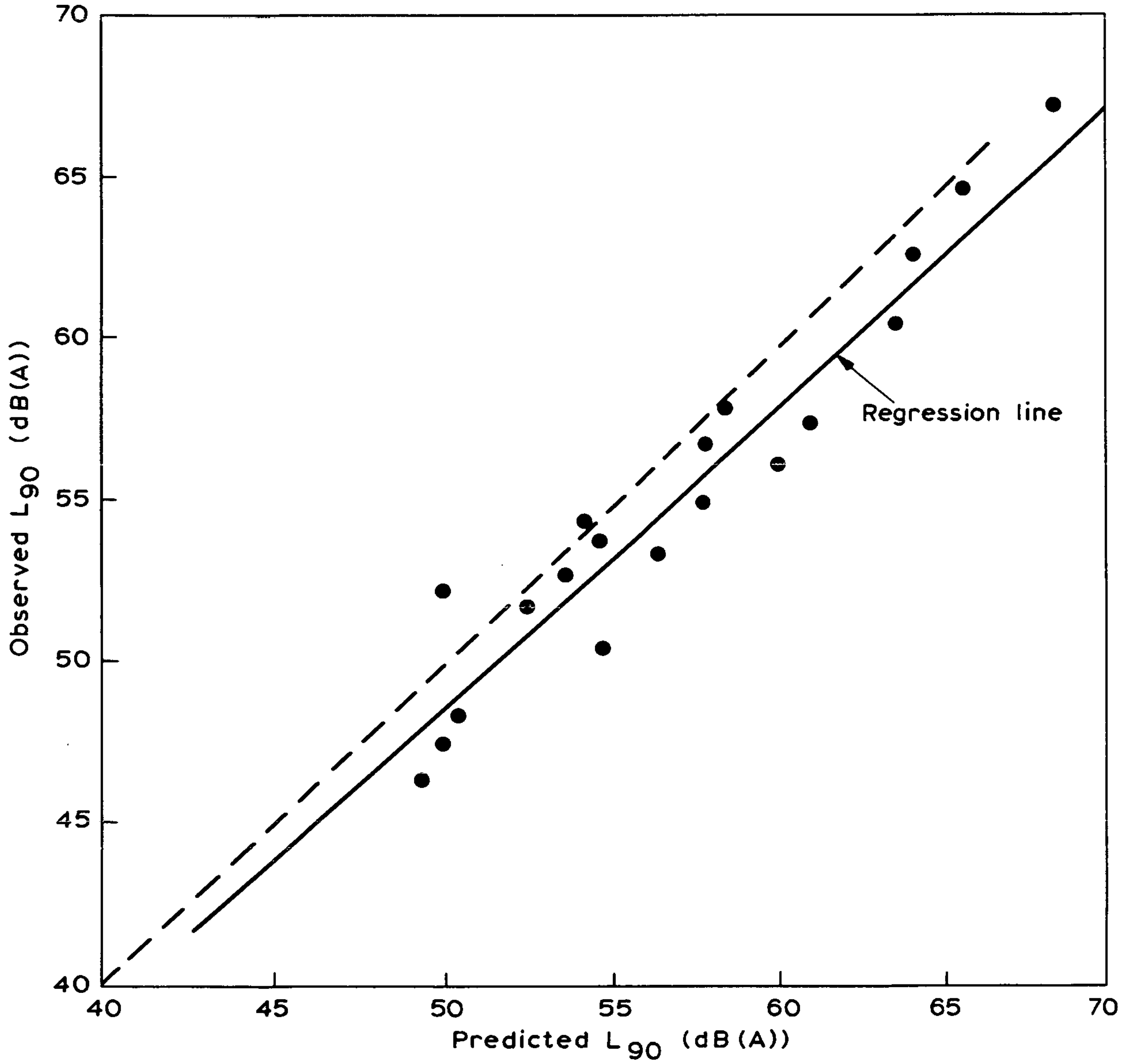

Fig. 7. COMPARISON OF OBSERVED AND PREDICTED L_{90} FOR SINGLE CARRIAGEWAY ROADS

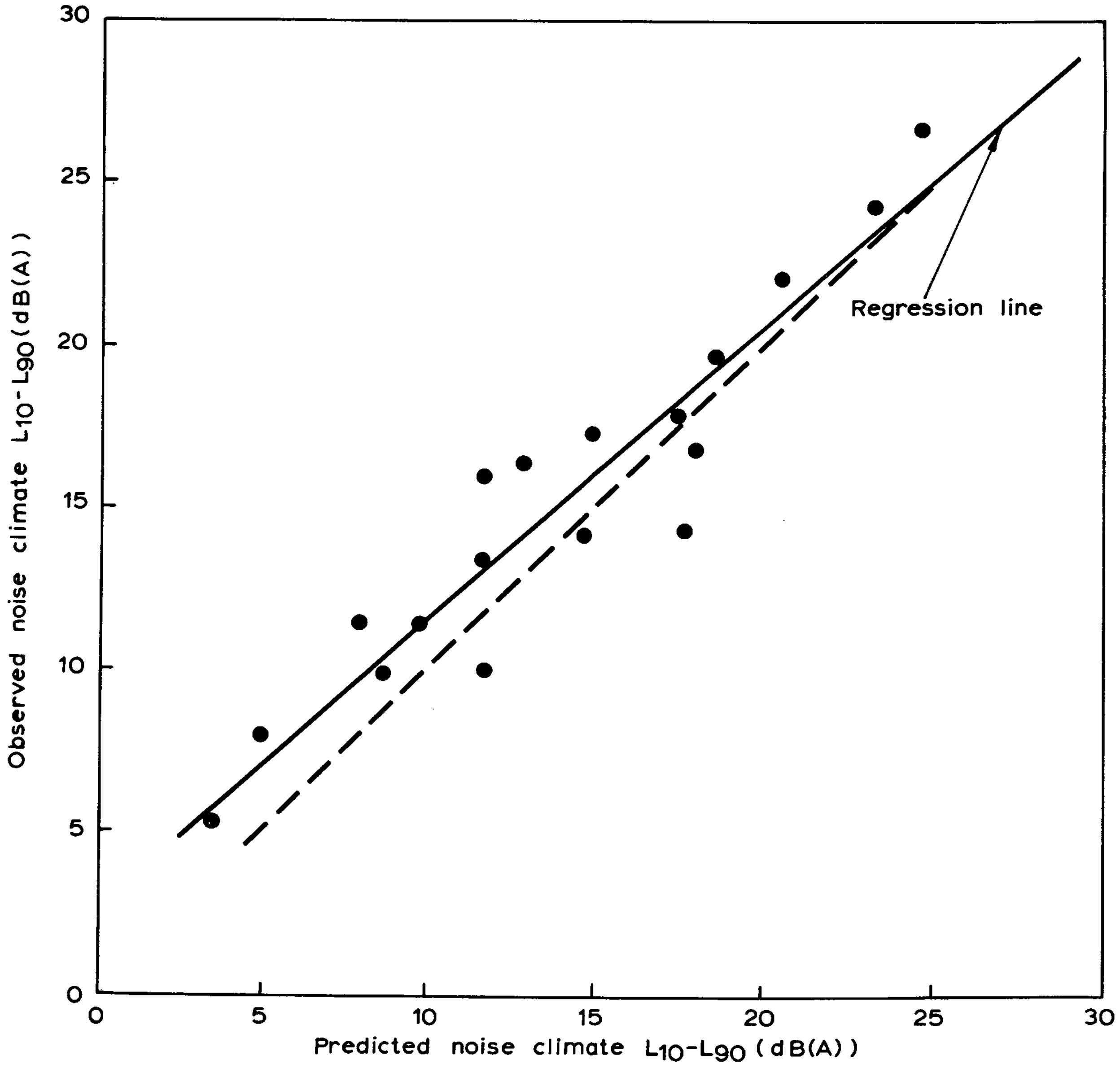

Fig.8 COMPARISON OF OBSERVED AND PREDICTED NOISE CLIMATE FOR SINGLE CARRIAGEWAY ROADS

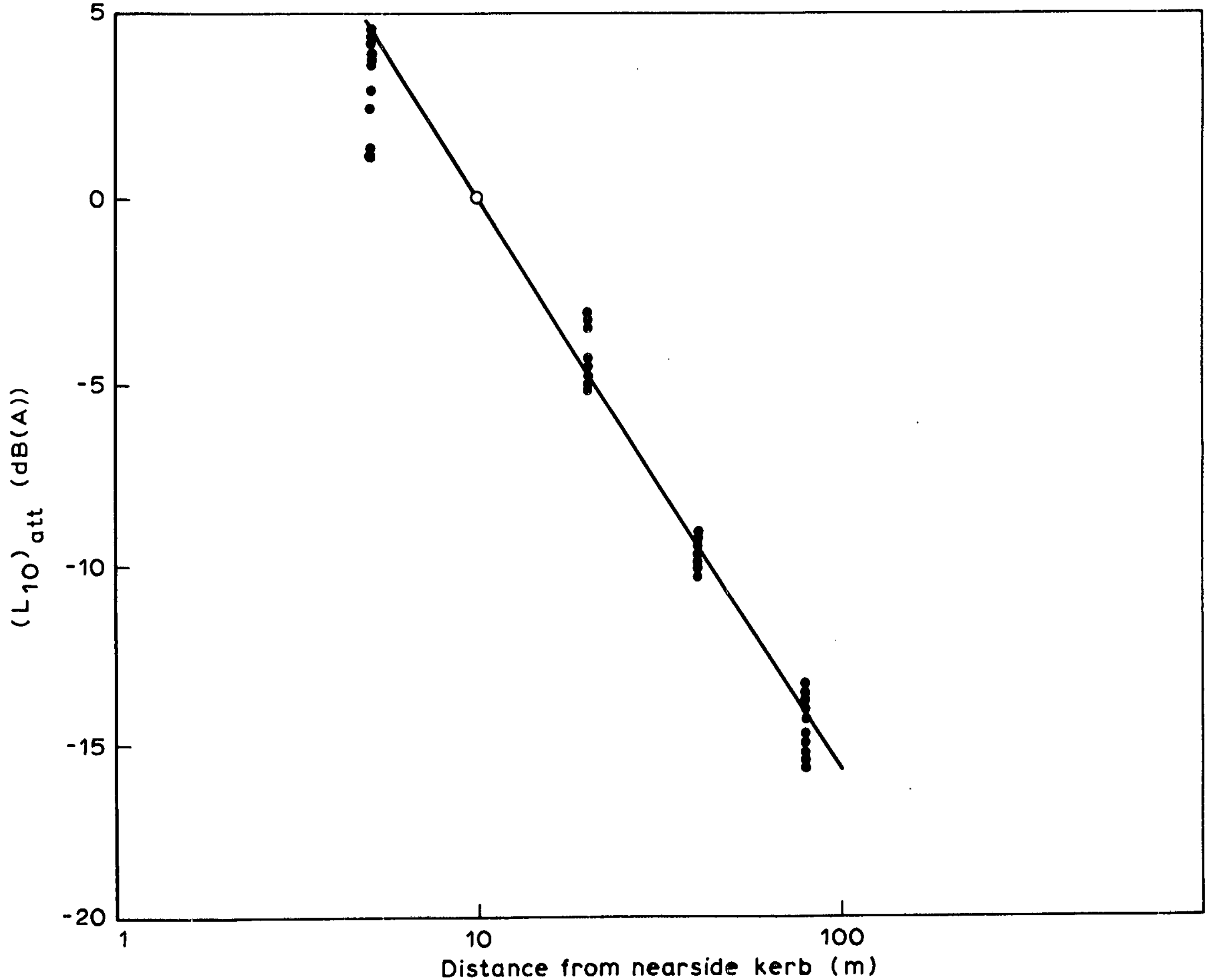

Fig. 9. VARIATION OF L_{10} WITH DISTANCE FOR PROPAGATION OVER SHORT GRASS

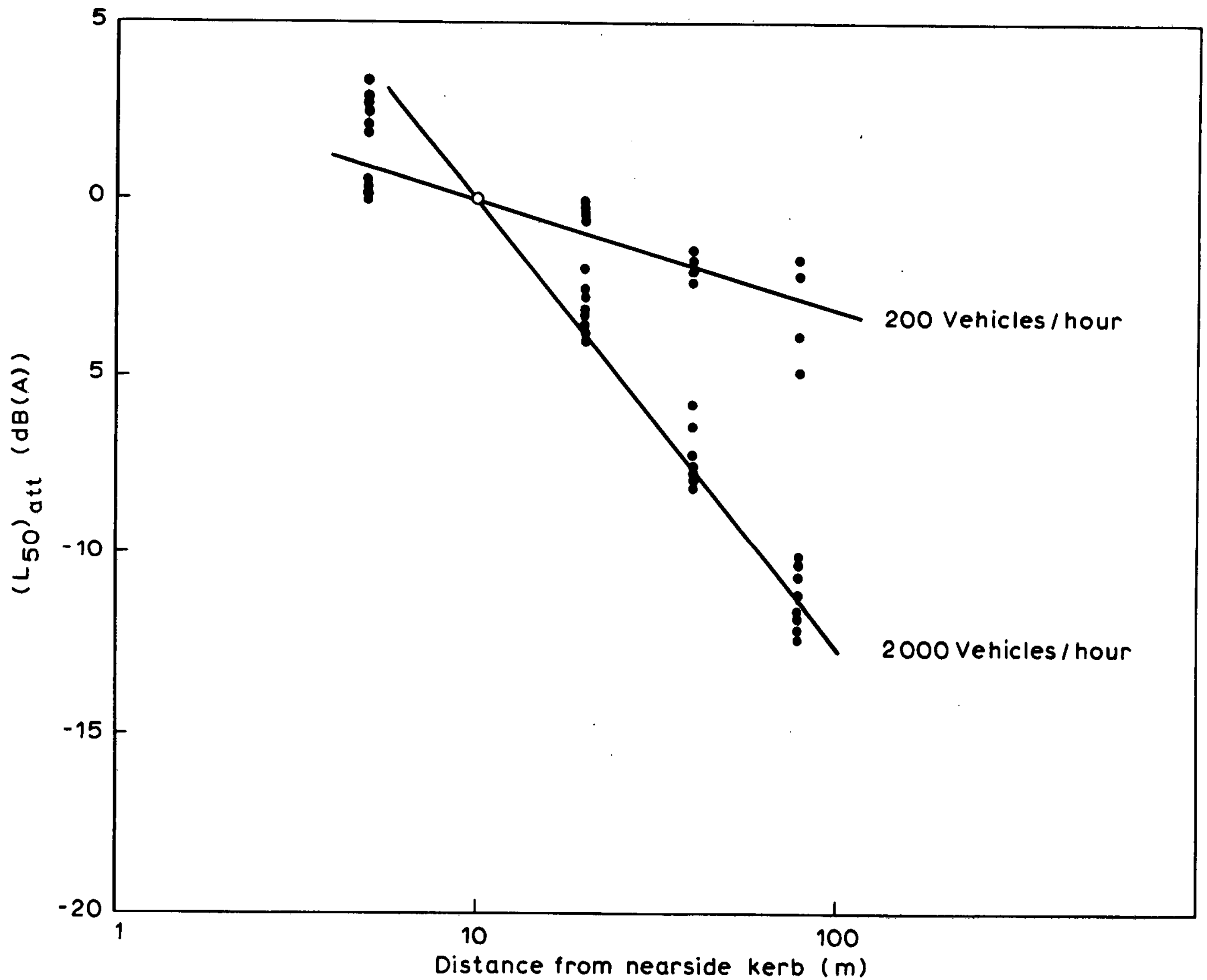

Fig. 10. VARIATION OF L_{50} WITH DISTANCE FOR PROPAGATION OVER SHORT GRASS

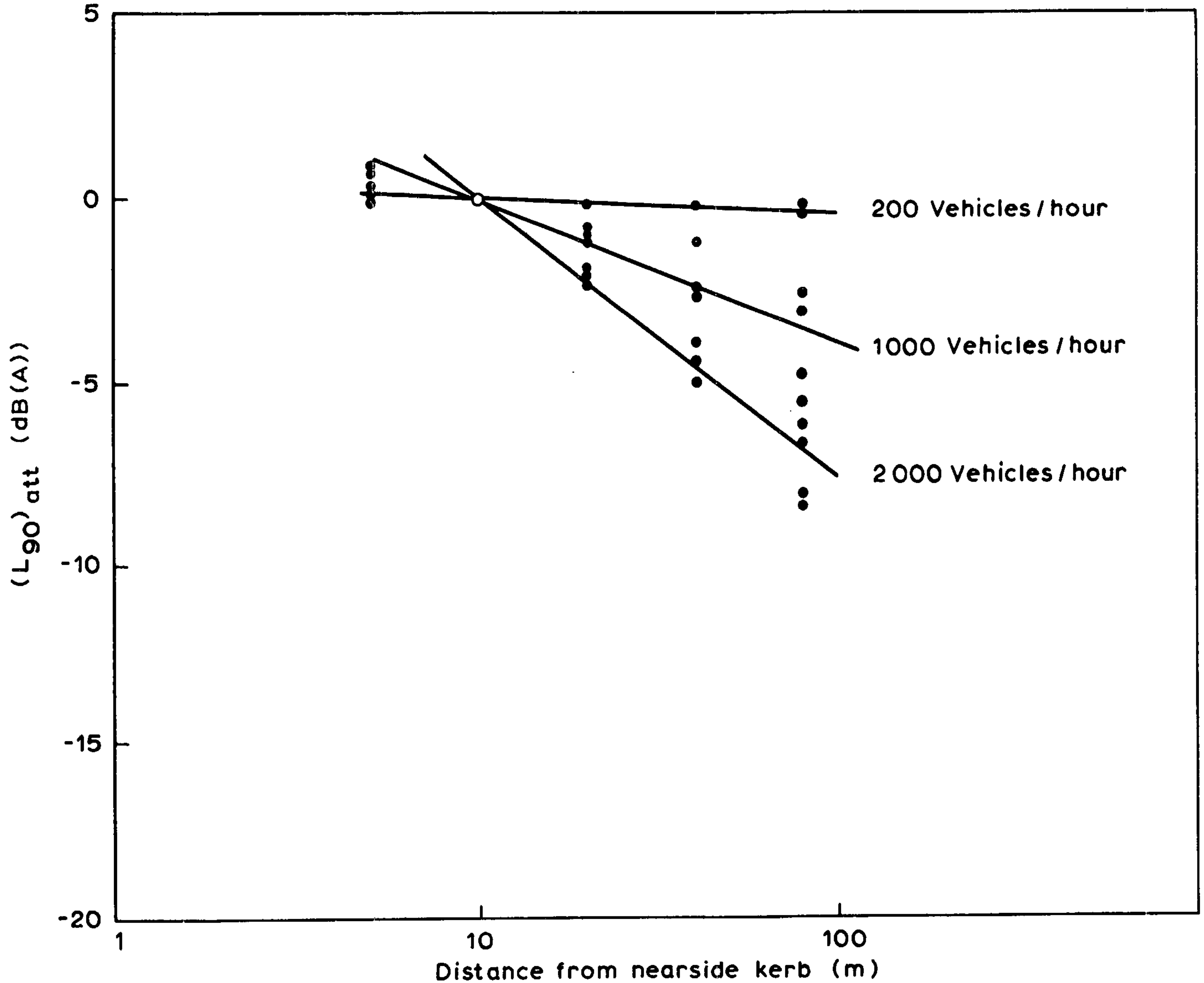

Fig. 11. VARIATION OF L_{90} WITH DISTANCE FOR PROPAGATION OVER SHORT GRASS

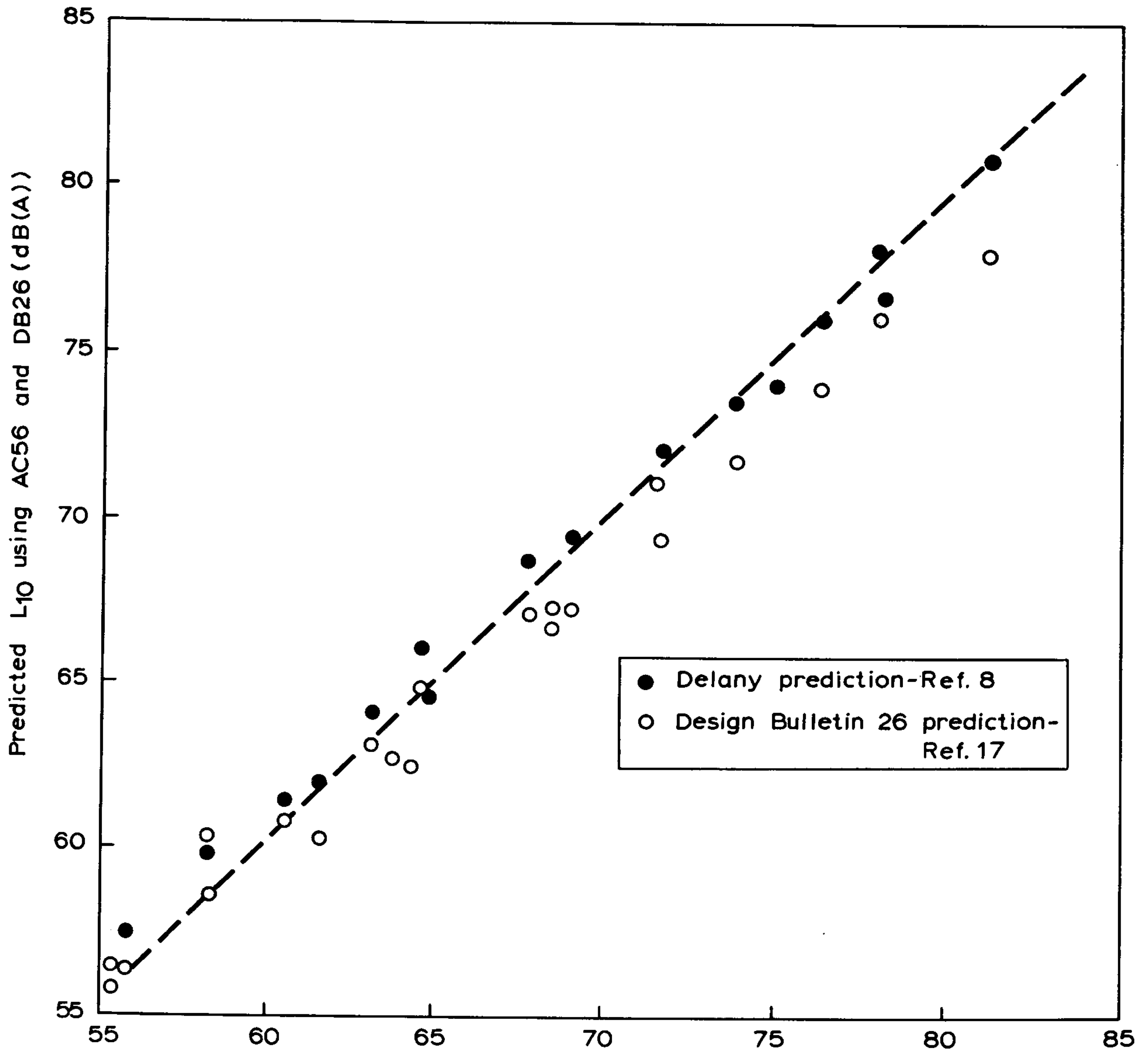

Fig. 12 COMPARISON OF THE L_{10} PREDICTIVE EQUATION WITH OTHER PREDICTIVE TECHNIQUES WHEN PROPOGATION IS OVER SHORT GRASS

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ABSTRACT

A computer model for determining the temporal distribution of noise from road traffic: P M NELSON, BSc, PhD, MInstP: Department of the Environment, TRRL Report LR 611: Crowthorne, 1973 (Transport and Road Research Laboratory). A new method is described for computing the temporal distribution of noise from freely flowing traffic, which is much faster than Monte Carlo models of similar sophistication. Validation studies indicate that the standard deviation of the observed values from the computed values of L_{10}, L_{50} and L_{90} are 1.1, 1.3 and 1.9 dBA respectively.

Using the model, simple equations have been derived relating L_{10}, L_{50} and L_{90} to the traffic flow, mean speed, proportion of lorries in the traffic stream and the distance from the roadway where the propagation is over grassland. The equations are designed primarily for traffic conditions beyond the range of applicability of existing prediction schemes yet are consistent with the conditions encountered in the majority of urban roadway networks.

The computer model can be readily extended to synthesize traffic noise in urban roadway networks and, in principle, noise from different transport modes. It is intended to develop the modelling technique further to construct an urban noise model incorporating complex roadway networks and ultimately various transport modes.

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