**Proceedings of the Institute of Acoustics**

# THE CALCULATION OF ROAD TRAFFIC NOISE – IMPLICATIONS OF CHANGING TO $L_{Aeq}$

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## 1. INTRODUCTION

Currently in the UK road traffic noise is assessed in terms of a measure derived from a statistical descriptor of the time varying noise level. The noise descriptor used, $L_{A10}$ dB(A) - the noise level exceed for 10 per cent of the time, was introduced in the UK in the early 70's, and was later adopted for noise control and regulation purposes in several other Commonwealth countries. However, it has not been adopted in the European Union, where the preferred scale is the energy average measure, $L_{Aeq}$. In addition, when considering noise from other transport modes the assessment of noise around British Airports and from railways is now carried out using the $L_{Aeq}$ scale. In the light of recent developments in Europe (Commission of the European Communities, 1996), which is moving towards the harmonisation of methods for assessing and predicting road traffic noise using $L_{Aeq}$, the continuing longer term use of the $L_{A10}$ scale in the UK must now be questioned. It was recognised some time ago that there was a case in the UK for a common approach to assessing environmental noise using $L_{Aeq}$. (Department of the Environment, 1990).

This Paper examines some of the implications of changing the current UK traffic noise prediction model from a method based on the $L_{A10,\ 18h}$ exposure to one based on $L_{Aeq}$. The discussion examines the mathematical relationship between the two scales and examines the possibility of deriving $L_{Aeq}$ values from $L_{A10}$ for different traffic parameters and site layouts. The implications of changing from $L_{A10}$ to $L_{Aeq}$ are also examined for a range of factors associated with road traffic noise legislation and planning policy. Other implications of a change to $L_{Aeq}$, such as comparing the correlation with annoyance, public understanding, and the monitoring and prediction of road traffic noise are not considered as part of this Paper.

## 2. RELATIONSHIP BETWEEN $L_{A10}$ AND $L_{Aeq}$

In general, road traffic noise at a given location is the combination of the individual noise from each vehicle that comprises the traffic stream. For freely flowing traffic and where traffic flows exceed about 100 vehicles per hour the distribution of noise levels approximate closely to a Gaussian distribution. By using this assumption relationships have been derived to link the statistical noise indices, $L_{A10}$ and $L_{Aeq}$ with the standard deviation, $\sigma$, of the distribution (Lamure, 1975), such as

$$L_{A10} - L_{Aeq} = 1.28\sigma - 0.115\sigma^2 \qquad (1)$$

For freely flowing traffic, $\sigma$ is often in the range 3-7, and equation (1) can then be approximated by the familiar form: -

$$L_{A10} - L_{Aeq} = 3\ dB(A) \qquad (2)$$

The Noise Advisory Council has reviewed empirically derived relationships between $L_{A10}$ and $L_{Aeq}$ (The Noise Advisory Council, 1978). Their findings showed that for the majority of situations of practical interest, the value of $L_{Aeq}$ over a specified period may be derived from values of $L_{A10}$ measured over the same time period by subtracting 3 dB. It suggested that for 95% of such conversions, the estimated $L_{Aeq}$ would be within ± 2 dB of the true value. However, under certain traffic and site conditions this simplistic conversion is no longer valid. For example, under low flow conditions, $L_{Aeq}$ may exceed $L_{A10}$ (Brown, 1989; Burgess, 1978). This is illustrated in Figure 1 which shows the difference between $L_{A10}$ and $L_{Aeq}$ derived from a theoretical study carried out for the Federal Highway Administration in the USA (Barry et al 1978).

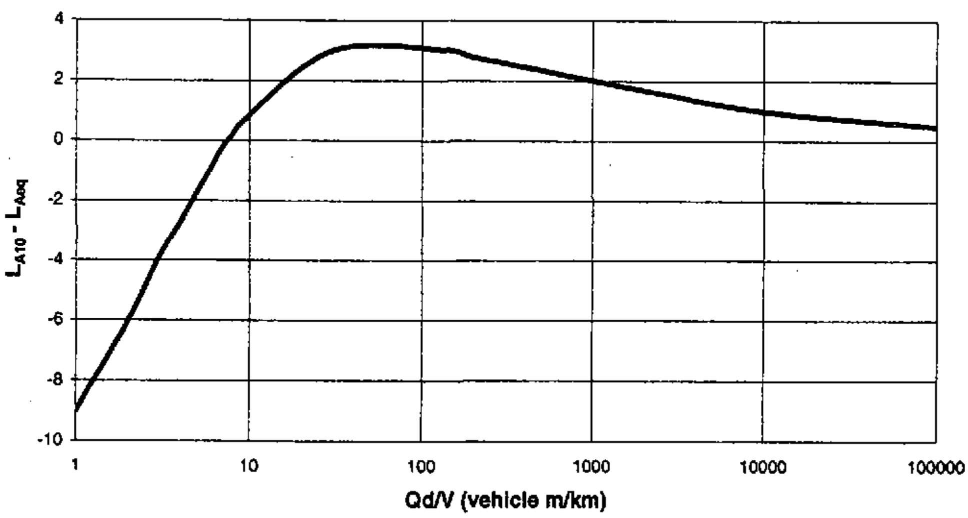


**Figure 1. Theoretical difference between $L_{A10}$ and $L_{Aeq}$**

The Figure shows that for open site propagation the difference between $L_{A10}$ and $L_{Aeq}$ is a function of the traffic flow (Q veh/h), distance from the road (d m) and the average vehicle speed (V km/h). To understand this complex relationship it is helpful to imagine that as the function Qd/V decreases the noise will tend to consist of relatively long periods of low noise levels separated by short periods of relatively high noise levels. Alternatively, as the function increases the fluctuation in noise level reduces. For low flow situations and for positions located close to a road, $L_{A10}$ is less affected by the occasional high noise level than $L_{Aeq}$ and may lead to $L_{Aeq}$ exceeding $L_{A10}$ as indicated in the Figure. These conditions might occur at night or where the noise level distribution is characterised by infrequent very noisy events such as might occur near to an access road to a quarry carrying heavy vehicles but with low traffic volume. As the function, Qd/V increases the difference between $L_{A10}$ and $L_{Aeq}$ increases rapidly and then becomes relatively stable with $L_{A10}$ exceeding $L_{Aeq}$ by about 3 dB, which is generally regarded as typical for most situations.

Further increases in the function Qd/V indicate that the difference between $L_{A10}$ and $L_{Aeq}$ reduces, with differences reaching about 0.5 dB(A) at the highest values in the range. Generally, therefore, this indicates that, at some distance from the road, as flow increases the rate of change in $L_{A10}$ will be less than for $L_{Aeq}$, although this will be moderated because as flow rate increases the speed of vehicles tend to reduce as the road becomes congested. Alternatively, where traffic flows are high and road speeds are constant, noise levels described on the $L_{A10}$ scale will attenuate at a greater rate with distance than described using $L_{Aeq}$. Examining Equation (1) also supports this effect. As the receiver moves further away from the road the variation in noise level decreases, $\sigma \rightarrow 0$ and the difference between $L_{A10}$ and $L_{Aeq}$ tends to zero.

The influence of noise variation on the relationship between $L_{A10}$ and $L_{Aeq}$ is also important when considering screening. Results from studies examining the performance of roadside barriers have shown that barriers reduce noise variability (Scholes et al, 1974). In general, therefore, barriers may have a larger effect on $L_{A10}$ than on $L_{Aeq}$. Theoretical studies carried out by Fisk indicate that this effect is progressive as the screening potential of the barrier increases and is dependent on vehicle speed and traffic flow (Fisk, 1975). This may be an important consideration if $L_{Aeq}$ were to replace $L_{A10}$ for noise assessment. In practical terms noise barriers may need to achieve a greater degree of screening to achieve the same reduction in noise level when assessed using $L_{Aeq}$ rather than $L_{A10}$. This may mean that barriers would be a more expensive means of achieving a given degree of noise level protection when using the $L_{Aeq}$ scale of assessment than in the past. Further analysis is required to quantify this effect.

A further aspect to be considered when examining the complex relationship between $L_{A10}$ and $L_{Aeq}$ is in the derivation of the index, $L_{A10,18h}$, which is defined as the arithmetic average of the 18 hourly $L_{A10,1h}$ values from 0600 to 2400 hours. Over the same time period, the $L_{Aeq,18h}$ index may be derived from a logarithmic average of the 18 hourly $L_{Aeq,1h}$ values. The difference, therefore, between these two indices will not only depend on the distribution of noise levels within each hour, as discussed above, but also on the diurnal variation of the individual hourly values. For example, if we assume a 3 dB(A) difference between hourly values of $L_{A10,1h}$ and $L_{Aeq,1h}$ as shown in Equation (2), the difference between the indices, $L_{A10,18h}$ and $L_{Aeq,18h}$, will also be 3 dB(A) but only if all the hourly values are the same. Generally, as the diurnal variation in hourly values increase the difference between the indices, $L_{A10,18h}$ and $L_{Aeq,18h}$ will be less than 3 dB(A). This is a consequence of the different averaging processes. Any low noise level hours included in the period will reduce the magnitude of the arithmetically averaged $L_{A10,1h}$ value relatively more than the logarithmic averaged $L_{Aeq,1h}$ value. This has important implications for determining equivalent criteria levels used in existing legislation and noise planning policy.

## 3. LEGISLATION AND NOISE PLANNING POLICY

This section deals with the implications of changing to $L_{Aeq}$ for traffic noise assessment on legislation and noise planning policy used in the UK. It is concerned with the specific documents which form part of DETR's policy on road traffic noise which include:

(a) The Noise Insulation (Amendment) Regulations 1988 (House of Commons, 1988)

(b) The Design Manual for Roads and Bridges (Department of Transport, 1994)

(c) Planning Policy Guidance: Planning and Noise PPG/24 (Department of the Environment, 1994)

Each of these documents relies on procedures for measuring or predicting the noise from road traffic as set out in 'Calculation of Road Traffic Noise' (Department Transport and the Welsh Office, 1988).

(a) The Noise Insulation (Amendment) Regulations 1988.

The Noise Insulation Regulations allows entitlement to sound insulation against increased noise from new or altered highways. The qualifying level for insulation is $L_{A10,18h}$ of 68 dB(A) provided certain other conditions are also met (see below). From the relationship between $L_{A10}$ and $L_{Aeq}$ which holds over a fair range of noise levels, it would appear reasonable to conclude that the equivalent qualifying level in terms of $L_{Aeq,18h}$ should be 65 dB(A). However, it is important to ensure that, as far as possible, all properties which qualify for insulation under the existing rules would also qualify if the criteria for compensation is changed to $L_{Aeq,18h}$ of 65 dB(A). However, the discussion in section 2 of this Paper demonstrated that the relationship between the two scales is not straightforward and is further complicated by the averaging process applied to each index.

Further evidence of divergence in the relationship may be found from studies which have looked at the relationship between $L_{A10,18h}$ and $L_{Aeq,24h}$ derived from empirical data covering a wide range of traffic conditions where noise levels, $L_{A10,18h}$, were in the range 60 to 75 dB(A). The average difference between $L_{A10,18h}$ and $L_{Aeq,24h}$ ranged from 3.2 to 3.7 dB(A) (Brown, 1989; Watts, 1984; Department of Transport, 1991). In order to compare the indices derived in these studies over the same 18-hour period it is necessary to make some assumptions about the variation in noise over a 24-hour period. For example, if it is assumed that the night-time noise levels between 0600 and 2400 hours are on average 10 dB below the daytime levels (Department of Transport, 1991) then $L_{Aeq,24h} = L_{Aeq,18h}$ - 1.1 dB. By applying this correction to the empirically derived differences given above, the noise level differences between $L_{A10,18h}$ and $L_{Aeq,18h}$ would be in the range 2.1 to 2.6 dB(A). This indicates that the correction factor of 3 dB(A) would be conservative in most cases.

To obtain a more direct comparison between the two indices, the results from a 50 site survey referred to earlier (Watts, 1984) were re-examined to provide a regression relationship between $L_{A10,18h}$ and $L_{Aeq,18h}$ for noise levels, $L_{A10,18h}$, over the range 58 to 76 dB(A) to give:

$$L_{A10,18h} = 1.07\, L_{Aeq,18h} - 2.60 \qquad (3)$$

With a correlation r = 0.99 and a mean difference between $L_{A10,18h}$ and $L_{Aeq,18h}$ of 2.2 dB(A).

Equation (3) implies that 68 dB(A) $L_{A10,18h}$ is equivalent to 65.9 dB(A) $L_{Aeq,18h}$ and provides further support in setting the criteria for compensation to 65 dB(A) $L_{Aeq,18h}$. Properties which qualify for noise insulation under the current legislation would most probably still qualify if a new threshold level were to be set at 65 dB(A) using $L_{Aeq}$.

Since the slope coefficient in equation (3) is close to unity, (i.e. 1.07) it can be concluded that over the range 60 - 75 dB(A) changes in the noise index, $L_{Aeq,18h}$, will be numerically similar to changes in the noise index, $L_{A10,18h}$.

Entitlement to noise insulation also requires that the noise from the new highway contributes at least 1 dB(A) to the overall noise outside the property. The method used for combining noise levels affects assessment against this criterion. The procedure described in the Technical Memorandum 'Calculation of Road Traffic Noise' (Department of Transport and the Welsh Office, 1988) for combining noise levels, $L_{A10,18h}$, assumes a simple energy summation. Although this procedure is an approximation for combining noise levels measured on the $L_{A10,18h}$ scale, it is mathematically precise when combining noise levels using the $L_{Aeq,18h}$ scale.

(b) Design Manual for Roads and Bridges (DMRB).

The Design Manual for Roads and Bridges: Volume 11 Environmental Assessment (Department of Transport, 1994) gives guidance on the environmental assessment of trunk road schemes including motorways; Part 7 deals with noise and vibration. Procedures for estimating changes in traffic noise nuisance when a new road scheme is planned are included in Part 7. This procedure relies on the results from surveys which have examined the relationship between objective measures of road traffic noise, $L_{A10,18h}$, outside residential properties and the percentage of people bothered by road traffic noise. Figure 2, curve (1), shows the relationship for the noise index $L_{A10,18h}$ derived from studies in which the noise exposure has been fairly stable and provides an estimate of traffic noise nuisance prior to the construction of the new road.

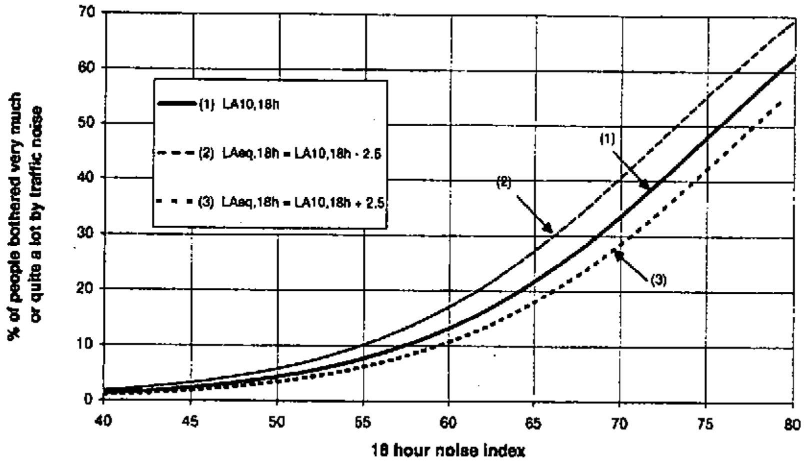


**Figure 2. Estimation of traffic noise nuisance prior to road construction for different noise indices.**

If the assessment procedure were to use the noise index $L_{Aeq,18h}$ rather than $L_{A10,18h}$ then a different response curve would need to be derived. Earlier in this section it was shown that from empirical studies based on a 50 site survey, the average difference between $L_{A10,18h}$ and $L_{Aeq,18h}$ was 2.2 dB(A), a constant difference of 2.5 dB(A) will be assumed at this stage for simplicity. Figure 2, curve (2), shows the relationship for the noise index $L_{Aeq,18h}$ based on this assumption. However, the relationship was based on studies of sites where daytime noise levels were greater than about 55 dB(A). Residents living in rural areas where traffic flows are low may be exposed to traffic noise where differences between $L_{A10,18h}$ and $L_{Aeq,18h}$ are less than 2.5 dB(A) and it has already been shown that under certain traffic and site conditions $L_{Aeq,18h}$ may even exceed $L_{A10,18h}$. To illustrate the effect such divergence might have on the relationship in Figure 2, curve (3) shows the shift in the curve produced by assuming that $L_{Aeq,18h}$ exceeds $L_{A10,18h}$ by 2.5 dB(A).

It is evident that as noise levels decrease, the difference in the estimated percentage of people bothered derived from the response curves reduces. If curve (2) were to replace curve (1) in estimating the degree of bother from noise levels in $L_{Aeq,18h}$, the percentage of people bothered prior to road construction may be slightly overestimated at sites where existing noise levels are low i.e. below about 55 dB(A). It is worth considering the use of equation (3) to convert the response curve for use with $L_{Aeq}$ noise levels, even though it is based on data within a restricted range of exposures.

Having obtained an estimate of the percentage of peopled bothered by traffic noise prior to road construction, the DMRB procedure requires the immediate effect of the change in traffic noise after the new road is open to traffic to be estimated. Figure 3 shows the relationship between the change in percentage of people bothered and the change in noise level, $L_{A10,18h}$, used in the DMRB procedure. Providing the relationship between $L_{A10}$ and $L_{Aeq}$ is constant over the range of the measured noise change, then changes in noise levels measured on the $L_{Aeq}$ scale will be numerically equivalent on the $L_{A10}$ scale. This was shown earlier to be a reasonable assumption for noise levels in excess of about 60 dB(A). With this proviso, the relationship shown in Figure 3 should also be valid for changes in $L_{Aeq,18h}$. However, where noise levels are low, the relationship between $L_{A10,18h}$ and $L_{Aeq,18h}$ is likely to vary, particularly where traffic flow is light. Under these circumstances, $L_{Aeq,18h}$ values may be similar or exceed $L_{A10,18h}$ values. Consequently, the change in the percentage of people bothered is likely to be underestimated in situations where noise levels prior to road construction are low and a large increase in noise occurs after the road is open. It is therefore recommended that the surveys which were used in developing the functions relating changes to traffic noise nuisance with changes in noise level, $L_{A10,18h}$, are re-examined. Provided that, at the time of the surveys, $L_{Aeq,18h}$ values were also measured, then a modified function relating changes to traffic noise nuisance to changes in noise level, $L_{Aeq,18h}$, could be established.

(c) Planning Policy Guidance: Planning and Noise. PPG/24.

This PPG gives guidance to local authorities in England on the use of their planning powers to minimise the adverse impact of noise and introduces the concept of Noise Exposure Categories (NEC) for residential development. Each NEC (A to D) provides advice on granting planning permission by taking into account the noise from individual noise sources i.e. road, rail and air traffic or from mixed sources i.e. the combined noise from several sources including industrial noise sources. A range of day and night-time noise levels for each noise source is attributed to each NEC. Each range of noise levels are expressed in terms of $L_{Aeq,16h}$ (daytime period 07:00 - 23:00) and $L_{Aeq,8h}$ (night-time period 23:00 - 07:00).

It is clear that local planning authorities prefer to use the $L_{Aeq}$ scale for environmental noise assessment for all sources including the noise from road traffic. The present advice in the PPG is to use CRTN to predict traffic noise levels and provides guidance on converting $L_{A10,18h}$ to $L_{Aeq,16h}$ based on assumed differences between the indices for noise levels above 57 dB(A). However, there is no guidance on how to calculate future daytime road traffic noise levels, $L_{Aeq,16h}$ based on predicted $L_{A10,18h}$ noise levels below 57 dB(A) or how to calculate future night-time noise levels, $L_{Aeq,8h}$ from road traffic. There is therefore a clear benefit in developing a road traffic noise prediction model based on $L_{Aeq}$ noise levels as it would considerably simplify the procedures described in PPG 24.

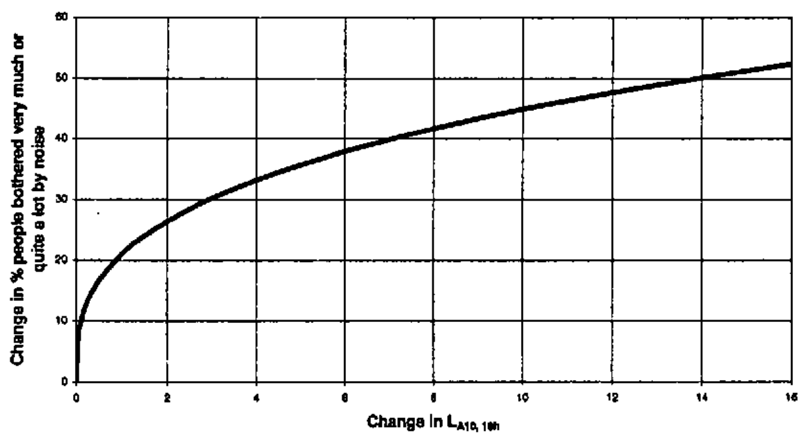


**Figure 3. Estimation of the change in traffic noise nuisance after the road is open to traffic**

# 4. CONCLUSIONS

1. Empirical studies suggest that where traffic noise levels exceed about 60 dB(A), $L_{A10,1h}$ will be about 3 dB higher than $L_{Aeq,1h}$. However, due to the diurnal variation in hourly values and the different averaging processes, differences between the noise indices, $L_{A10,18h}$ and $L_{Aeq,18h}$ will tend to be less than 3 dB(A). A value of 2.2 dB(A) was shown to be more typical.

2. Theoretical and empirical studies have shown that the relationship between the noise scales $L_{A10}$ and $L_{Aeq}$ is complex and that under certain conditions, typically when traffic flows are low, $L_{Aeq,1h}$, may exceed $L_{A10,1h}$. It was also shown that where traffic flows are high and traffic speeds are constant $L_{A10}$ may attenuate at a greater rate than $L_{Aeq}$ and that the screening performance of noise barriers may be greater when assessed in terms of $L_{A10}$ compared with $L_{Aeq}$.

3. Changing to $L_{Aeq}$ as the scale for assessing entitlement to insulation as the result of noise from road traffic will require changes to the Noise Insulation (Amendment) Regulations 1988. An equivalent qualifying noise level of 65 dB(A) $L_{Aeq,18h}$ would be appropriate. The qualifying increases in noise levels or contributions of 1 dB(A) need not be altered. It is likely that properties, which qualify for insulation under the existing rules, would also qualify if the recommendations described above were introduced.

4. Changing to $L_{Aeq}$ will affect the functions used for assessing noise nuisance given in Figures 2 and 3 in Part 7 of Volume 11 of the Highway Agency's Design Manual for Roads and Bridges. The function for estimating traffic noise nuisance prior to road construction, can be adjusted using a constant difference of 2.5 dB(A) to convert $L_{A10,18h}$ noise levels to $L_{Aeq,18h}$ or alternatively the regression function shown in equation 3 may be more appropriate. A constant difference implies that Figure 3 can be applied unaltered to changes in $L_{Aeq,18h}$ noise levels. However, it is important to note that this relationship between $L_{A10,18h}$ and $L_{Aeq,18h}$ breaks down where noise levels are lower than about 60 dB(A). It is likely that using Figure 3 to assess the effects of a new road in a previously quiet area would underestimate the effect of changes in $L_{Aeq,18h}$ noise levels. The surveys which were used as the basis of the functions relating changes to traffic noise nuisance with changes in noise level need to be re-examined and the incorporation of additional data considered to resolve the doubts in these cases.

5. The Government planning policy to protect new residential development against noise set out in PPG 24 recommends the use of the $L_{Aeq}$ scale for environmental noise assessment including that from road traffic. Although there is some guidance on converting $L_{A10,18h}$ to $L_{Aeq,16h}$ it does not include how to calculate future daytime road traffic noise levels, $L_{Aeq,16h}$ based on predicted $L_{A10,18h}$ noise levels below 57 dB(A) or how to calculate future night-time noise levels, $L_{Aeq,8h}$ from road traffic. There is therefore a benefit in developing a road traffic noise prediction model that calculates $L_{Aeq}$ noise levels and which would therefore improve the procedures described in PPG 24. A traffic noise prediction model based on $L_{Aeq,18h}$ would clearly simplify the procedures recommended in PPG24 for local planning authorities to assess environmental noise exposures in residential areas.

## 5. ACKNOWLEDGEMENTS

The work described in this project report was carried out for the Highways Agency of the Department of the Environment, Transport and the Regions (DETR).

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