

VOLUME 11 SECTION 3 PART 7
TRAFFIC NOISE AND VIBRATION

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1. INTRODUCTION

1.1 This chapter gives advice on the assessment of noise and vibration impacts due to road traffic.

2. TRAFFIC NOISE

2.1 The sources of noise from a traffic stream can be separated into two components. The first is generated by the engine, exhaust system and transmission and is the dominant noise source when traffic is not freely flowing particularly from heavy vehicles which contribute a significant proportion of low frequency noise. Noise levels, will vary primarily according to engine speed rather than vehicle speed. The second noise source component is generated from the interaction of tyres with the road surface and is the dominant noise source under free flow traffic conditions at moderate to high road speeds and contributes a significant proportion of high frequency noise. Noise levels will vary depending on vehicle speed, the road surface and whether the surface is wet or dry.

2.2 The noise from a stream of traffic at a reception point at any one instant is an aggregation of noise from each of many vehicles at various distances. Among factors which influence a basic traffic noise level are traffic flow, speed and composition (%HGVs), road gradient and road surface characteristics. The noise level at a particular reception point will also be affected by other factors among which are distance from the noise source, the nature of the intervening ground surface and the presence of obstructions.

Units of Measurement

2.3 A sound wave travelling through air is a regular disturbance in the atmospheric pressure. These pressure fluctuations are detected by the human ear, producing the sensation of hearing. The human ear is so constructed that it can respond to very small pressure fluctuations and the audible range is, therefore, very large.

2.4 Sound pressures are measured in units of pascals (Pa). The range of sound pressures, from the minimum detectable to the onset of pain is vast. To cope with such a range in values it is convenient to measure sound in terms of a logarithmic ratio of sound pressures. These values are expressed as sound pressure levels (SPL) in decibels (dB) and are defined as:

$$\text{SPL} = 20 \log (p/p_0) \text{ dB}$$

where p is the sound pressure and p_0 the sound pressure at the threshold of hearing.

The audible range of sounds expressed in terms of

sound pressure levels (dB) can now be conveniently covered within the range 0 dB (the threshold of hearing) to 120 dB (the threshold of pain).

A further advantage in adopting a logarithmic scale is that the response of the human hearing system to changes in noise level is logarithmic rather than linear in behaviour. Over most of the audible range, a subjective impression of a doubling in loudness corresponds to a 10 fold increase in sound energy which conveniently equates with an increase in sound pressure level of 10 dB. Doubling the energy level (for example the volume of traffic) increases the noise level by 3 dB.

2.5 The frequency of sound is the rate at which a sound wave oscillates, measured in number of cycles per second, or Hertz (Hz). The sensitivity of the human ear to different frequencies in the audible range is not uniform. For example, hearing sensitivity decreases markedly as frequency decreases below about 250Hz. A further complication is that the variation with frequency is a function of the sound level, the variation being less for very loud sounds than those near the hearing threshold. Experience has shown that in order to rank the noisiness of road vehicles the sound pressure level has to be adjusted to give comparatively more weight to the frequencies which are detected most readily by the human ear. Several different weightings have been proposed but the 'A' weighting has been found to give one of the best correlations with the perceived noisiness of vehicles. Logically the characteristics of the weighting should be slightly different for higher level sounds. Other weightings such as 'B' and 'C' have been proposed which are similar in concept to the 'A' weighting. However, these alternative measurement scales are seldom used for traffic noise assessment as they do not offer any advantage over the measurements taken using the dB(A) scale. An indication of the level of some common sounds on the dB(A) scale is given in Figure 1.

2.6 The noise from a traffic stream is not constant but varies from moment to moment and it is necessary to use an index to arrive at a single-figure estimate of the overall noise level for assessment purposes. The index adopted by the Government to assess traffic noise is $L_{A10,18h}$ which is the arithmetic mean of the noise levels exceeded for 10% of the time in each of the 18 one hour periods between 6am and midnight. (Note: 'A' in the subscript denotes that the sound levels have been 'A' weighted). A reasonably

good correlation has been shown to exist between this index and residents' dissatisfaction with existing traffic noise over a wide range of exposures. In addition, the prediction and measurement techniques are well known and well developed.

2.7 An alternative index is the equivalent continuous sound level, L_{Aeq} which is defined as the level of that (notional) steady sound that, over the period of measurement, would deliver the same noise energy as the actual intermittent or time varying noise. Using this measure, a fluctuating noise can be described in terms of a single noise level over the same exposure period. It is particularly suitable for describing a noise which consists of occasional short periods of noise between relatively long quiet periods - for example to assess noise from construction and demolition sites and to determine noise from railways and aircraft. However, it does not provide a better correlation with people's dissatisfaction with road traffic noise than L_{A10} .

2.8 A scale which is sometimes used to describe background noise levels is L_{A90} , which is the level exceeded for 90% of the time. This index may give a more realistic indication of noise changes in rural areas at a considerable distance from a new road because in such circumstances the main noise effect is likely to be on background noise levels. However, its usefulness as an indicator of noise impact is uncertain at the present time and more research is needed to assess how it correlates with people's reactions to noise and how it can be modelled.

2.9 For the purposes of assessing the noise from road traffic it is important that the rules for combining noise levels from different traffic sources are understood. If two sources of traffic noise occur together the resultant noise level can be calculated by adding a correction to the higher of the two noise levels. The correction is dependent on the difference in level between the two noises. Where the difference between the two noise levels is zero, ie the two levels are identical, 3 dB(A) is added to either noise level to obtain the combined value. Where there is a 6 dB(A) difference, the combined level is obtained by adding only 1 dB(A) to the higher of the two noise levels. (The procedure for combining noise levels from several sources is illustrated in Chart 11 of Calculation of Road Traffic Noise, DTp/Welsh Office, 1988)

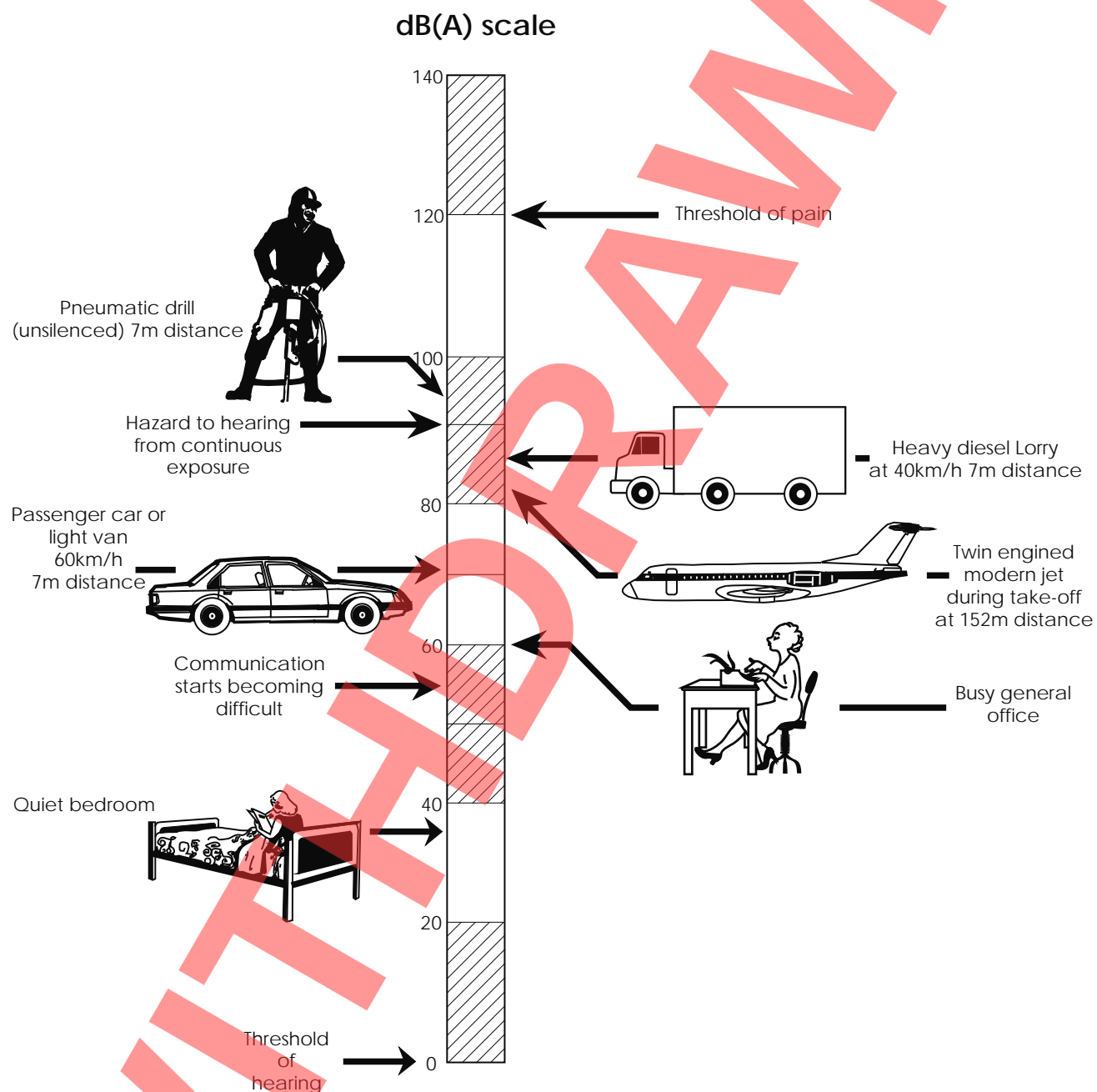


Figure 1. The level of typical common sounds on the dB(A) scale

3. NUISANCE FROM TRAFFIC NOISE

3.1 The World Health Organisation definition of noise nuisance is 'A feeling of displeasure evoked by noise'. The nuisance caused by noise mainly affects people in their homes or when they are in the streets. However, areas of open space that are also used for recreational purposes can also suffer from noise pollution.

3.2 Attempts to measure noise nuisance usually make use of questionnaire surveys. The surveys attempt to relate annoyance expressed by the people interviewed with some physical measurement of the noise causing the annoyance. These surveys have revealed that individuals vary considerably in their sensitivity to noise and this is reflected in their ratings of traffic noise nuisance. In addition it has been found that attitudes to traffic noise are also related to satisfaction with the neighbourhood in general.

3.3 Given this variability in individual responses practical research has moved from the ideal of explaining individual attitudes or annoyance with noise and instead adopted the concept of an average or community annoyance rating for each noise level.

Summary of main research into traffic noise nuisance

3.4 Many surveys have investigated the relationship between traffic noise and its impact on people. "Nuisance" is often used as a general term to describe this impact, and surveys usually employ ratings on scales such as satisfaction-dissatisfaction or "bother" as a way of measuring it. Much of the survey work has compared noise and nuisance levels at sites where conditions were generally steady - ie no sudden changes in exposure had recently taken place or were in prospect. Such surveys yield "steady state" relationships between noise exposure and nuisance.

3.5 In recent years, evidence has also been accumulating from surveys before and after sudden changes in noise exposure. It indicates that people are more sensitive to abrupt changes in traffic noise associated with new road schemes than would be predicted from the steady state evidence. In the period following a change in traffic flow, people may find benefits or disbenefits when the noise changes are as small as 1dB(A) - equivalent to an increase in traffic flow of 25% or a decrease in traffic flow of 20%. These effects last for a number of years. In the longer term, perceived noise nuisance may tend towards the steady state level associated with the new

noise exposure.

3.6 Figure 2 shows a "steady-state" relationship between noise exposure and noise nuisance, derived from three surveys (Morton-Williams, Hedges and Fernando, 1978, Watts, 1984 and Huddart, 1994). An earlier version of this document (DMRB 11, 1993) used a curve based on the first of these surveys only. ANNEX I discusses the reasons for this change. Nuisance here is measured as the percentage of people bothered by traffic noise (ie those who say they are "very much" or "quite a lot" bothered on a four point worded scale). Figure 3 shows a relationship between changes in noise nuisance (on the same nuisance scale) and changes in noise exposure. This curve was based on data from surveys by TRL (Huddart and Baughan, 1994) and by Griffiths and Raw (1986), adjusted as described in Annex I. It shows much greater changes in nuisance than would be predicted from the steady state curve of Figure 2. Figure 3 gives the change in nuisance soon after a change in noise. As mentioned above, the new level of nuisance indicated by Figure 3 appears to persist for several years at least; but in the longer term nuisance levels will probably tend towards those predicted by the steady-state relationship of Figure 2.

3.7 Research has been conducted into the relationship between sleep disturbance, as reported in social surveys, and noise exposure, as measured or predicted by acousticians. There tends to be a rather poor correlation between reported awakenings and recorded intrusive events and, similarly, rather poor correlations between reported sleep quality and observed behaviour such as awakening or changes in sleep stage patterns. Measurements of noise from roads in Britain and Germany both show that night-time traffic noise (ie, noise between 10pm and 6am on the following day) is on average 10 dB(A) less than daytime levels (Railway Noise and the Insulation of Dwellings, DoT, 1991).

3.8 In 1982 Rice and Morgan produced a comprehensive synthesis of field and laboratory studies and suggested that sleep disturbance could be significant at quite low noise levels. In 1992, the Department of Transport completed a major study into aircraft noise and sleep disturbance. This study was based on collecting objective data on how people slept in their own homes under normal circumstances. This was done by using actimeters, a wrist-watch sized computer that is put on at night to measure limb

movements (which correlate well with sleep disturbance). Data were collected on 400 subjects for 15 nights each. This was the largest set of such data ever collected.

3.9 Aircraft noise has many characteristics similar to traffic noise at night. Movements by aircraft tend to occur at irregular intervals and the level of activity is far below normal daytime levels. The main findings of this study were that, once asleep, very few people living near airports are at risk of any substantial sleep disturbance due to aircraft noise, even at the highest event noise levels above 100 dB(A). At outdoor peak noise levels below 80 dB(a), average sleep disturbance rates are unlikely to be affected by aircraft noise. At higher levels, and most of the noise data on which the conclusions were based were in the range 80-95 dB(A) L max, the chance of the average person being awakened is about 1 in 75. Compared with the overall average of about 18 nightly awakenings from other causes, this probability indicates that even large numbers of noisy night time aircraft movements will cause very little increase in the average person's night awakenings. Therefore, based on expert opinion on the consequences of sleep disturbance, the results of this study provide no evidence to suggest that aircraft noise is likely to cause harmful after effects. (Report of a Field Study of Aircraft Noise and Sleep Disturbance, DoT 1991)

3.10 If the results of this study are broadly valid for road traffic then it would suggest that the risk if sleep disturbance from traffic noise at night is very small, and certainly well below the levels suggested by previous studies or analysis.

Data table for Figure 2.

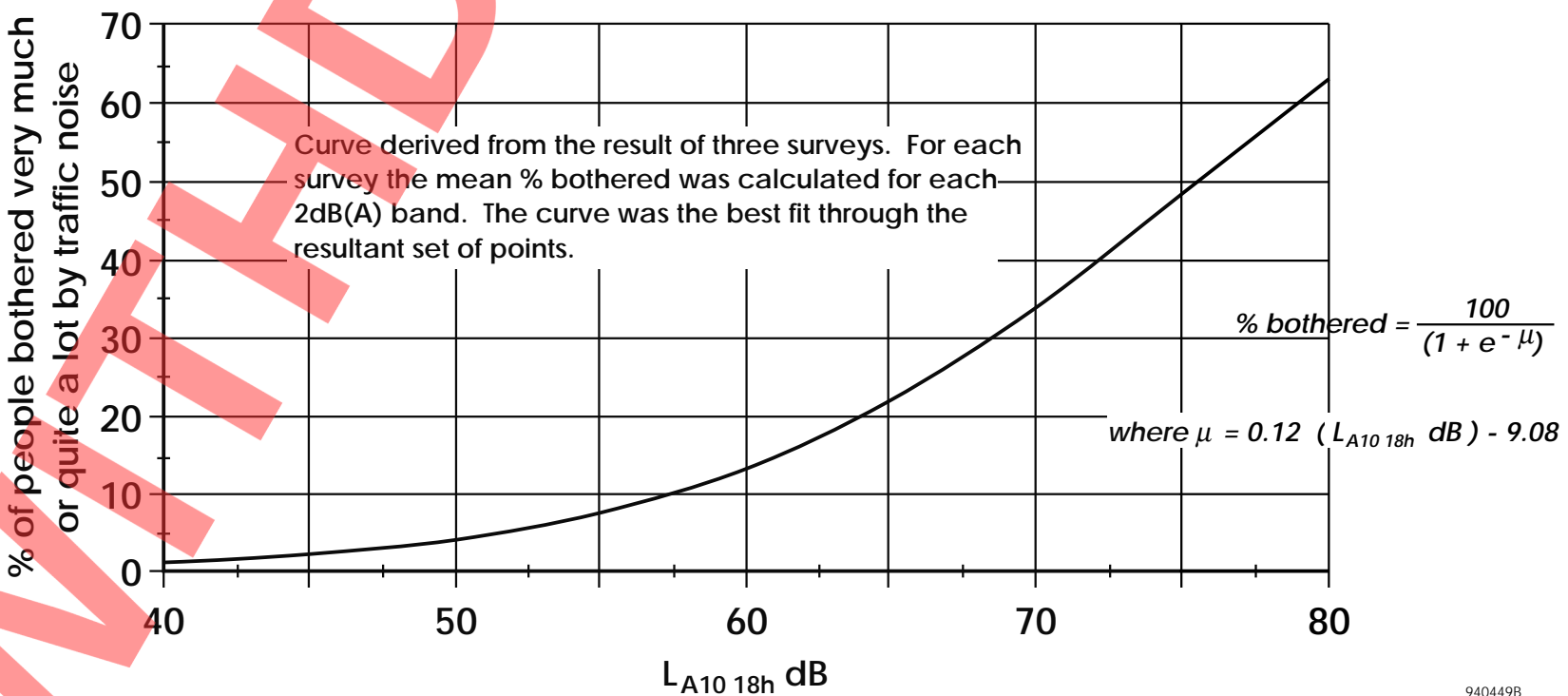
Estimation of percent bothered very much or quite a lot by traffic noise under steady-state conditions or before traffic noise change.

L _{A10 18h} dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
40	1	1	1	1	1	1	1	1	2	2
41	2	2	2	2	2	2	2	2	2	2
42	2	2	2	2	2	2	2	2	2	2
43	2	2	2	2	2	2	2	2	2	2
44	2	2	2	2	2	2	2	2	2	2
45	2	2	3	3	3	3	3	3	3	3
46	3	3	3	3	3	3	3	3	3	3
47	3	3	3	3	3	3	3	3	3	3
48	3	4	4	4	4	4	4	4	4	4
49	4	4	4	4	4	4	4	4	4	4
50	4	4	4	5	5	5	5	5	5	5
51	5	5	5	5	5	5	5	5	5	5
52	6	6	6	6	6	6	6	6	6	6
53	6	6	6	6	6	7	7	7	7	7
54	7	7	7	7	7	7	7	7	8	8
55	8	8	8	8	8	8	8	8	8	9
56	9	9	9	9	9	9	9	9	9	10
57	10	10	10	10	10	10	10	10	10	11
58	11	11	11	11	11	11	11	12	12	12
59	12	12	12	12	12	13	13	13	13	13
60	13	13	14	14	14	14	14	14	14	15
61	15	15	15	15	15	15	16	16	16	16
62	16	16	17	17	17	17	17	17	18	18
63	18	18	18	18	19	19	19	19	19	20
64	20	20	20	20	21	21	21	21	21	22
65	22	22	22	22	23	23	23	23	23	24
66	24	24	24	25	25	25	25	25	26	26
67	26	26	27	27	27	27	28	28	28	28
68	28	29	29	29	29	30	30	30	30	31
69	31	31	32	32	32	32	33	33	33	33
70	34	34	34	34	35	35	35	36	36	36
71	36	37	37	37	37	38	38	38	39	39
72	39	39	40	40	40	41	41	41	41	42
73	42	42	43	43	43	44	44	44	44	45
74	45	45	46	46	46	47	47	47	47	48
75	48	48	49	49	49	50	50	50	50	51
76	51	51	52	52	52	52	53	53	53	54
77	54	54	55	55	55	55	56	56	56	57
78	57	57	58	58	58	58	59	59	59	60
79	60	60	60	61	61	61	62	62	62	62
80	63	63	63	64	64	64	64	65	65	65

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Estimation of traffic noise nuisance

Steady state or before noise change



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Data table for Figure 3.

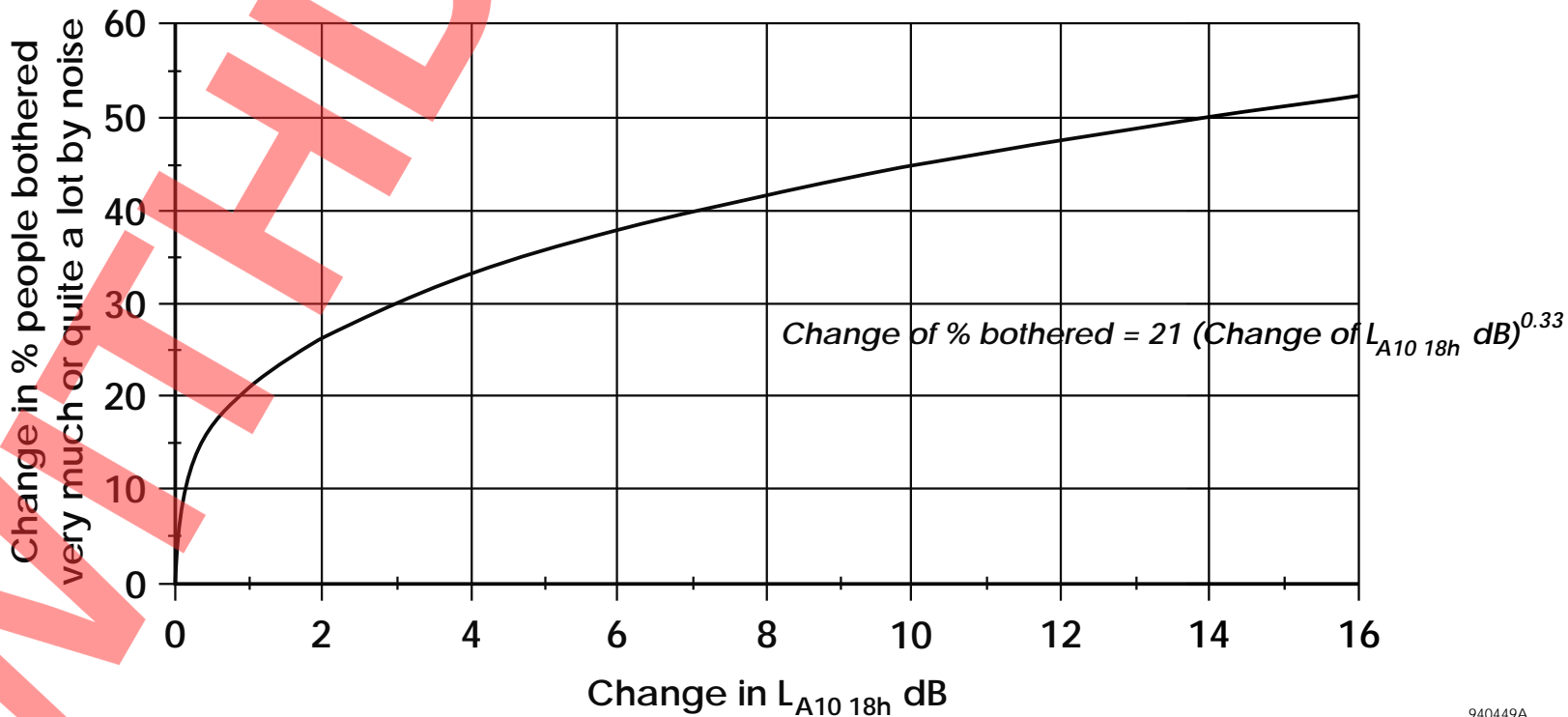
Change in the percentage of people bothered very much or quite a lot by traffic noise.

Change in $L_{10\ 18h}$ dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	21	22	22	23	23	24	25	25	25	26
2	26	27	27	28	28	28	29	29	29	30
3	30	31	31	31	31	32	32	32	33	33
4	33	33	34	34	34	34	35	35	35	35
5	36	36	36	36	37	37	37	37	38	38
6	38	38	38	39	39	39	39	39	40	40
7	40	40	40	40	41	41	41	41	41	42
8	42	42	42	42	42	43	43	43	43	43
9	43	44	44	44	44	44	44	44	45	45
10	45	45	45	45	45	46	46	46	46	46
11	46	46	47	47	47	47	47	47	47	48
12	48	48	48	48	48	48	48	49	49	49
13	49	49	49	49	49	50	50	50	50	50
14	50	50	50	51	51	51	51	51	51	51
15	51	51	52	52	52	52	52	52	52	52
16	52	53	53	53	53	53	53	53	53	53

940449Cp2

Estimation of traffic noise nuisance

Change in % bothered very much or quite a lot by traffic noise.



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4. NOISE SURVEYS

4.1 The objective of the noise assessment is to establish the magnitude and significance of noise changes for all areas where existing traffic is likely to be increased by 25% or reduced by at least 20% (equivalent to a change in noise levels of 1dB(A)). Particular care should be taken to identify locations which are especially sensitive to noise or vibration. Schools, hospitals, homes for the blind and Aged Persons homes come into this category. Outdoor areas which are commonly used by people and which have a low ambient level (ie, below 50 dB(A)) should also be identified.

4.2 Although the noise calculations are based on future traffic flows, the effect of the changes has, of necessity, to be recorded for the existing properties and people and no attempt should be made to predict land use or occupancy changes. Where planning permission has been granted but not implemented the number of additional properties affected should be recorded separately and reported.

5. MEASURING AND PREDICTING NOISE LEVELS AND ASSESSING NOISE NUISANCE

5.1 To forecast the change in noise level caused by a road scheme at any given location, it is necessary to know the site's ambient noise level and predicted noise level after the scheme has been opened. All noise levels should be rounded to the nearest 0.1 dB(A).

Ambient Noise Level

5.2 Ambient noise is defined as the level of noise in an area before the change produced by the scheme under consideration has taken effect. It may include traffic noise, as well as noise from other sources. In certain cases, allowance will need to be made for changes in ambient noise levels which are expected to occur between the time of the assessment and the time when the scheme is planned to open (for example, as a result of a proposed new industrial estate or the intensified use of a car park). In such cases, these effects should be noted separately.

Predicting and Measuring Noise Levels

5.3 The aim of Calculation of Road Traffic Noise CRTN and the Memorandum on the Noise Insulation (Scotland) Regulations 1975 is to permit calculation of road traffic noise levels in most situations. Calculations of noise changes should be carried out for both the scheme opening year and the worst year in the first fifteen years after opening. The traffic flow to be used in the calculations shall be the maximum expected between 06.00 hrs and midnight on a normal working day within a period of 15 years after opening to traffic. High traffic growth should be assumed. The following paragraphs give a brief outline of the CRTN calculation method. They do not give detailed guidance; for this refer to the source documents.

5.4 Section I of CRTN sets out a step by step method for predicting noise levels at a distance from a highway, taking into account such factors as traffic flow, speed and composition, road configuration, intervening ground cover between source and listener, screening (barriers, buildings and land form), angle of view of the traffic and reflections from facades. Section II provides additional advice on procedures which may need to be used to calculate noise in special situations (for example, at road junctions, or for roads with very low traffic flows).

5.5 The final figure calculated is strictly applicable to only one position, usually one metre from the relevant facade of a building and at a stated height above ground. However, by carrying out calculations at a few representative positions, other facade levels can be interpolated with acceptable accuracy. The calculations are valid between 4 m and 300 m from the nearest point on the carriageway. For facades closer than 4m from the edge of the carriageway it may be assumed that changes in noise levels can be estimated from prediction of noise levels at 4m from the edge of the carriageway. Beyond 300m the varying effects of wind and temperature render forecasting difficult in most circumstances. However, in quiet rural areas, where there is a low density of roads and houses, traffic noise impact may be appreciable more than 300m from the carriageway. In such a case the change in noise may be approximately determined by the method set out in TRRL Supplementary Report 425 "Rural Traffic Noise Prediction - An Approximation".

Measuring Noise Levels

5.6 Direct measurement with a noise meter is recommended in CRTN when there is a need to know existing levels and where, for example, traffic conditions fall outside the range of validity of the charts given in CRTN. Ambient noise can vary over wide ranges. There are three basic types of ambient situation which can occur:-

- (i) where the ambient noise is dominated by traffic noise;
- (ii) where the ambient noise is comprised of a combination of several undefined sources such as might be encountered in low noise sites in rural settings; or
- (iii) where the ambient noise is dominated by noise from non-road traffic sources such as aircraft or trains.

5.7 For condition (i) ambient noise can be measured using L_{A10} . Care is needed in the interpretation of the levels of the $L_{A10, 18h}$ recorded. These will vary from day to day during the year, depending on the influence of varying traffic and weather conditions and seasonal effects. Variations

are particularly noticeable when the propagation distance is large. Therefore, in order to estimate the annual average ambient noise levels a series of measurements taken on several occasions during the assessment period should be used. Where a strong prevailing wind is known to exist between the road and the listener, or vice versa, measurements should also be taken in those conditions to assist in the interpretation of the nuisance caused by predicting levels which assume moderately adverse wind conditions. Section III of CRTN gives further guidance on the measurement of $L_{A10, 18h}$.

5.8 For condition (ii) there is no clearly discernible traffic noise and so current methods of assessment using $L_{A10, 18h}$, which is specific to traffic noise, may be inappropriate. Although there is at present no generally accepted method for assessing the impact of traffic noise in such situations, some form of assessment will be needed. It would appear reasonable, under these circumstances, to determine the ambient noise using an alternative noise scale such as L_{A90} , which is the level exceeded for 90% of the time. Alternatively the scale of L_{Aeq} could be used to assess the ambient levels, but this measure is very susceptible to short duration high noise levels that might occur, for example, from an overflying aircraft, a passing train or from barking dogs, and for this reason it would appear not to be an appropriate measure to use in assessing general levels of ambient noise in this type of environment. Consequently, it is recommended that pending more detailed research on this topic, the ambient noise level should be determined from measurements of $L_{A90, 18h}$ taken over several days during the assessment period to determine the influence of different weather conditions. Once the range of conditions has been established an average value can be determined. The assessment would then be based on comparing the $L_{A10, 18h}$ for the new road with the average (ambient) $L_{A90, 18h}$ for the area. Before undertaking measurement work the advice of the Local Authority Environmental Health Officer should be sought as to whether relevant ambient noise data already exist.

5.9 For condition (iii) the ambient noise will most likely be characterised by long periods of relative quiet followed by intermittent higher noise levels generated by passing trains or aircraft. For these situations, it is recommended that the ambient noise is measured during the periods of relative quiet when the non-road traffic sources are not operating. If the noise during these periods is clearly generated mainly by existing road traffic the use of the $L_{A10, 18h}$ index is appropriate, otherwise the $L_{A90, 18h}$ index is recommended.

5.10 For the prediction of noise nuisance changes, the difference between current nuisance levels and the worst nuisance levels expected in the first 15 years after the change are calculated. To do this, the research results described in Chapter 3 should be applied as described below. Worked examples are given in ANNEX II.

(a) **changes in noise levels due to traffic growth for the 'Do Minimum' alternative**

Do minimum

If only gradual changes in noise exposure are likely, the 'steady state' curve (Figure 2) should be used to estimate current and future nuisance levels (ie percentage bothered). Alternatively the Figure 2 data table may be used which presents the same relationship in tabular form. The 15th year nuisance levels are likely to be the worst, in which case the change in nuisance is simply the difference between the 15th year value and the current value of nuisance.

(b) **changes in noise levels following the opening of the road**

Increases in noise

Current nuisance is estimated from Figure 2. The immediate increase in nuisance is estimated from Figure 3, and the new level of nuisance is the sum of these values. This is the level that is expected soon after the scheme is opened and for several years afterwards. It will usually be the highest level to be expected in the first 15 years and so is the level to use when estimating the change in nuisance for Table 1. The change in nuisance can therefore be read directly from Figure 3. Where there is doubt whether the highest level of nuisance will occur soon after the scheme opens, this can be checked by comparing it with the 15th year level as estimated from Figure 2.

Decreases in traffic noise

The current nuisance level is estimated from Figure 2. Again, Table 1 requires the change in nuisance based on the highest nuisance in the first 15 years after opening. Generally this will be the 15th year value from Figure 2, and so the change in nuisance can be estimated by subtraction, using values from Figure 2. Where there is doubt whether the highest level of nuisance will occur in the 15th year, it can be checked against that expected soon after the scheme opens. The immediate decrease is estimated from Figure 3. the new nuisance level is the current level minus the decrease, except if this results in a negative value, then a value of zero per cent should be used instead.

Using the highest level of nuisance in the first fifteen years after a change means that for most situations

where traffic levels have decreased the immediate benefit, as shown in Figure 3, is ignored. For a scheme where this benefit is thought to be particularly important, a special note should be made in Table 1, specifying the size of the immediate decrease in nuisance.

Limitations of the method

The surveys on which this method was based were conducted at sites where road traffic was the dominant noise source and ranged from 65 to 78 dB $L_{A10, 18h}$, the changes in traffic noise were up to 10 dB $L_{A10, 18h}$ and the dwellings were up to 18 metres from the kerb. Strictly, the method should not be used outside the noise and distance ranges covered by the surveys, or when the ambient noise is not from traffic.

However, it seems likely that the mechanisms underlying the survey results will operate outside these ranges. Until better information becomes available, it is recommended that the method is used to predict nuisance changes outside these noise and distance ranges, albeit with caution. When the pre-scheme noise level is not dominated by traffic noise, it will be measured using the noise index $L_{A90, 18h}$ (see paras 5.8 and 5.9). Again, until better information becomes available, it is recommended that $L_{A90, 18h}$ is used to estimate pre-scheme levels of nuisance, instead of $L_{A10, 18h}$ in these situations, using Figure 2. When estimating the change in nuisance from Figure 3, the difference between the "after" level of noise as $L_{A10, 18h}$ and the "before" noise level as $L_{A90, 18h}$ should be used.

Survey data from sites where traffic noise increased are rather limited, but in the absence of more complete information, it is recommended that the method is used for traffic increases, but with caution.

The method is based on surveys of noise changes caused by changes in traffic flow. It will not necessarily give a good prediction if traffic noise changes were brought about by some other means, such as barriers or low noise road surfaces. Further research is required before traffic noise nuisance changes can be estimated for these situations.

(c) Changes in sleep, disturbance due to traffic growth.

5.11 An estimate of possible sleep disturbance may be based on the research described in Chapter 3.

5.12 Identify those properties where traffic noise would be increased above $68dB(A)_{L_{10, 18h}}$ and where the average weekday flow between 10pm and 6am is

likely to exceed 10% of the total.

6. VIBRATION

Introduction

6.1 Traffic vibration is a low frequency disturbance producing physical movement in buildings and their occupants. Vibration can be transmitted through the air or through the ground. Air borne vibration from traffic can be produced by the engines or exhausts of road vehicles with dominant frequencies in the 50-100 Hz range. Ground borne vibration is more often in the 8-20 Hz range and is produced by the interaction between rolling wheels and the road surface.

6.2 Vibration can be measured in terms of peak particle velocities, or PPVs (ie, the maximum speed of movement of a point in the ground during the passage of a vibration). For traffic vibration generally a PPV of 0.2mm/s measured on a floor in the vertical direction is imperceptible; at about 0.5 mm/s it is perceptible and may become disturbing or annoying at higher levels. The level of nuisance caused will obviously depend on building type and usage. Occupants of hospitals, educational establishments and laboratories or workshops where high precision tasks are performed may well be affected to a greater extent than residents of domestic dwellings. PPVs in the structure of buildings close to heavily trafficked roads rarely exceed 2mm/s and typically are well below 1mm/s. Normal use of the building such as closing doors, walking on suspended wooden floors and operating domestic appliances will often generate much higher vibration levels. There is no firm evidence that structural damage to buildings can occur below approximately 10 mm/s. At the highest levels of traffic induced vibrations it is possible that architectural damage to plaster finished walls could occur if the high vibration persisted for many years.

Vibration Effects

6.3 There are two effects of traffic vibration that need to be considered: effects on buildings and disturbance to occupants.

Effects on Buildings

6.4 Ground-borne vibrations are produced by the movement of rolling wheels on the road surface and can be perceptible in nearby buildings if heavy vehicles pass over irregularities in the road. It has long been a popular belief that such vibrations can lead to damage in buildings. Extensive research on a

wide range of buildings of various ages and types has been carried out (TRL, Watts, 1990), but no evidence has been found to support the theory that traffic induced vibrations are a source of significant damage to buildings. Minor cracking of plaster may possibly occur at high exposure sites (ie, existing heavily trafficked roads with poor surfaces and subgrade conditions) but it is very unlikely that this would be distinguishable from cracking due to other causes. There was no evidence that exposure to airborne vibration had caused even minor damage.

6.5 Since significant ground-borne vibrations are generated by irregularities in the road surface they are unlikely to be important when considering disturbance from new roads, and an assessment will only be necessary in exceptional circumstances. Equally, as the road conditions which cause ground-borne vibration can be rectified during maintenance work, relief of such vibration should not be presented as a benefit of a new scheme.

Disturbance to Occupiers

6.6 Ground-borne vibration is much less likely to be the cause of disturbance than airborne vibration but where it is the cause its effects can be more severe. At highest risk are occupants of buildings on soft soils which are close to heavily trafficked older roads where the road surface is uneven or constructed from concrete slabs which can deflect under the weight of passing heavy vehicles. Ground-borne vibration levels depend on many factors and are therefore difficult to predict with precision, however peak levels and attenuation with distance can be estimated if the size of the road irregularity is known and the speed of traffic and type of sub-grade can be determined (Watts, 1990).

6.7 Traffic-induced vibrations from low frequency sound emitted by vehicle engines and exhausts can be a source of annoyance to local people and can occur to some extent along any type of road. Such sound may result in detectable vibrations in building elements (for example, windows, doors and, in some cases, floors), as reported in two surveys which investigated the relationship between physical measures of noise, vibration and traffic parameters, and measurements of nuisance obtained by interviews (Baughan and Martin, 1981; Watts, 1984). It was found that $L_{A10, 18h}$ index was among the physical variables most closely associated with average vibration disturbance ratings. The relationship between the percentage of people bothered by largely

airborne vibration and this noise exposure index is similar to that for noise nuisance except that the percentage of people bothered by vibration is lower at all exposure levels. For the purposes of predicting vibration nuisance the curve in Figure 2 should be employed by making a suitable adjustment to the percentage bothered. For a given level of noise exposure the percentage of people bothered very much or quite a lot by vibration is 10% lower than the corresponding figure for noise nuisance. On average traffic induced vibration is expected to affect a very small percentage of people at exposure levels below 58 dB(A) and therefore zero percent should be assumed in these cases.

6.8 The survey of vibration nuisance was restricted to properties within 40m of the carriageway where there were no barriers to traffic noise. When using this graph to make predictions of disturbance caused by airborne vibration, care is needed in cases where the buildings are screened or are not sited within 40m of the road.

7. POSSIBLE MITIGATION MEASURES

7.1 The assessment of noise and vibration should be based on the scheme with mitigation as agreed by the Overseeing Department.

7.2 Examples of possible mitigation techniques are described below. They generally apply to both noise and vibration attenuation.

- realigning a route away from residential areas or other sensitive locations;
- keeping a route low within the natural topography to exploit any natural screening and enhance this by the use of cuttings and, in exceptional circumstances, tunnels;
- providing environmental barriers, such as earth mounding or acoustic fencing. Conventional environmental barriers are not effective in reducing ground borne vibration and may be only partially effective against airborne vibration. They should therefore be ignored in assessing vibration nuisance unless more detailed tests show appreciable benefits from the design proposed;
- the use of alternative road surfaces.

7.3 Reducing the noise/vibration impact of a road is just one of the factors to be considered in route choice and design, and conflicts can exist. For example, an acoustic barrier may introduce unacceptable visual intrusion. In addition, any mitigation measure must perform to an acceptable level in traffic, road safety and economic terms.

8. STAGES IN THE ASSESSMENT OF NOISE AND VIBRATION IMPACTS

8.1 The noise and vibration assessment should become increasingly detailed as a scheme develops. It should both inform and take account of the selection of possible routes, and of the design of the preferred route. Assessment and design are part of an iterative process. Relevant mitigation measures, such as environmental barriers, should be taken into account, although possible noise insulation should not be included in the calculation of noise changes (the CRTN methodology applies to outdoor noise levels only).

8.2 The following levels of detail will generally be appropriate at the key stages.

Stage 1

8.3 The objective at this stage is to undertake sufficient assessment to provide an appreciation of the likely noise and vibration consequences from traffic associated with particular broadly defined routes, or corridors, as developed by the Design Organisation and agreed with the Overseeing Department's Project Manager.

8.4 The steps to take at this stage are:-

(i) identify existing roads and possible new routes or route corridors where traffic changes of plus or minus 25% are expected in the year the scheme is opened;

(ii) contact Local Authority Environmental Health Officers for any information about existing noise nuisance, either from traffic or other sources, such as factories or quarries. Also obtain information on any noise constraints arising from Local Plans;

(iii) identify areas which are especially sensitive to noise or vibration - for example, schools, hospitals, homes for the blind or for the Aged Persons, laboratories containing sensitive instruments, heritage buildings and outdoor areas commonly used by people where ambient noise levels are currently believed to be below 50 dB(A);

(iv) mark the sensitive locations

identified above on a map showing the existing route network and possible routes or route corridors;

(v) estimate the number of houses within 300 metres of existing roads subject to traffic changes of over 25%, using 100 metre bands from the centre-line (for urban schemes, the first 100m band should be replaced by two bands of 0-50m and 50-100m);

(vi) make similar estimates for possible new routes or route corridors.

8.5 The results of the assessment at this Stage, to be described in the Stage 1 Report, should be presented as follows:-

(a) a map showing noise-sensitive locations, the existing route network and route corridors;

(b) a statement on the significance of potential noise changes, both to local people in general and to sensitive locations in particular. The statement should identify route corridors where noise increases could require particularly extensive mitigation.

Stage 2

8.6 The objective at this stage is to undertake sufficient assessment to identify the noise and vibration effects to be taken into account by the Design Organisation in developing and refining route options in agreement with the Overseeing Department's Project Manager.

8.7 The steps to take at this stage are:-

(i) for each route option, prepare a map with 300m wide bands on either side of the centre-line divided into three 100m wide strips (for urban schemes, the first 100m strip should be replaced by two bands of 0-50m and 50-100m). Identify noise-sensitive locations within 300m of the centre-line;

(ii) estimate the number of properties

within 300m of each route option, using the bands 0-100m, 100-200m and 200-300m (for urban schemes, 0-50m and 50-100m should be used instead of 0-100m);

(iii) for noise-sensitive locations likely to be significantly affected by a route option, and for typical locations elsewhere in proximity to it, measure or calculate ambient and predicted noise levels to determine possible noise changes. Annotate this information on a map showing each route option, and estimate the distance(s) from the road at which noise changes will not be discernible. Where possible, noise maps should take account of agreed mitigation (although not of possible noise insulation of properties) and this assumption clearly stated. If this is not possible, a note should be made that estimates of noise increases do not take account of agreed mitigation and may exaggerate adverse impacts;

(iv) an accurate assessment of vibration nuisance is difficult to carry out. However, for unscreened buildings within 40m of an existing or proposed route option Figure 2 should be used to estimate the degree of airborne, traffic-induced vibration. Rarely, where ground-borne vibration on existing routes is likely to be a problem then measurements at the foundations of a sample of buildings considered to be at high risk will establish whether vibration levels are likely to exceed the threshold of perception. Based on these measurements an estimate should be made of the number of buildings likely to be exposed to perceptible vibrations along the route. The number of buildings and an indication of peak vibration levels (PPVs) should be included in the assessment. The DO should seek the approval of the Overseeing Department's Project Manager before undertaking any ground-borne vibration survey.

8.8 The result of the noise assessment at this Stage, to be included in the Stage 2 Report, should consist of:-

(a) a statement on the significance of potential noise changes, both to local people in general and to sensitive locations in particular, associated with the route options under consideration. The statement should consider possible reductions in noise levels along the existing road network, as well as

possible increases caused by possible new routes. It should identify route options where noise increases could require particularly extensive mitigation. Possible vibration impacts should be included in the statement where relevant;

(b) to illustrate the statement, maps for each route option under consideration showing the centre-line, the distance bands either side of it, any noise-sensitive locations and the ambient and predicted noise levels for the latter and for typical locations along the route.

Stage 3

8.9 The steps to take at this stage are:-

(i) conduct a noise assessment of all properties and other relevant locations (for example, sports fields, canals, footpaths) where existing traffic is likely to be increased by at least 25% or reduced by at least 20%. The assessment should show predicted noise changes [all changes in noise levels should be calculated to the nearest 0.1 dB(A)] and noise nuisance changes estimated as described in paragraph 5.10. Agreed mitigation should be taken into account (excluding probable noise insulation).

The assessment noise levels should classify locations according to their ambient levels, in bands of below 50 dB(A), 50-<60 dB(A), 60-<70 dB(A) and ≥ 70 dB(A). For each ambient noise band, the number of properties and other locations subject to the following increases or decreases should be included: 1-<3 dB(A), 3-<5 dB(A), 5-<10 dB(A), 10-15 dB(A) and over 15 dB(A). All noise calculations should be based on the maximum traffic flow expected on a normal working day during the first 15 years after opening, using the highest traffic forecast. Parallel calculations should be made for the do minimum option.

A noise nuisance assessment should be made for properties when the noise change is 1 dB(A) or more. The number of properties subject to the following increases or decreases in the percentage of people bothered by noise should be included: <10 percentage points, 10-<20 percentage points, 20-<30 percentage points, 30-<40 percentage points, or ≥ 40 percent points. All calculations should be based on the

highest nuisance levels expected during the first 15 years after opening. When the scheme will cause noise increases this will usually be the nuisance level experienced soon after opening as estimated using Figure 3. For noise decreases and the do-minimum situation, the highest nuisance experienced during the first 15 years after opening will usually be that in the 15th year, estimated from Figure 2. For decrease sites when the immediate reduction in nuisance (estimated from Figure 3) is felt to be important, this shall also be noted in Table 1. All noise predictions should be based on the highest traffic forecasts.

- (ii) where necessary, include a note on traffic-induced vibration in the assessment, following the guidance in CHAPTER 6;

8.10 The result of the assessment at this Stage, to be included in the Environmental Statement, should consist of:-

- (a) a statement of ambient and predicted noise levels for all properties and other relevant locations, with plans showing the impacts at key and typical sites after taking account of agreed mitigation. The statement should relate noise changes to the research evidence on noise nuisance. It should also note that the assessment takes no account of possible noise insulation, and should briefly explain the Noise Insulation Regulations and indicate the number of properties which are likely to be eligible for statutory insulation. Where appropriate, the statement should also include an assessment of traffic-induced vibration.

EXTRACT OF A STAGE 3 NOISE ASSESSMENT SUMMARY TABLE

		Residential		Commercial		Industrial		Community Facilities		Comments
		Preferred Route	Do Minimum	Preferred Route	Do Minimum	Preferred Route	Do Minimum	Preferred Route	Do Minimum	
Ambient Noise Band	50-60									
L _{A10 18h} dB										
Increase in Noise Level	1 < 3	100	200	10	6	0	1	Footpath No 9	Town Common Broughton Hospital	Broughton Hospital has 250 beds ¹ Affected industrial premises all engaged in heavy engineering works
	3 < 5	225	100	5	0	0	0			
	5 < 10	52	0	0	0	3 ¹	0	Canal Towpath		
	10 < 15	22	0	0	0	0	0			
	>= 15	0	0	0	0	0	0			
L _{A10 18h} dB										
Increase in Nuisance Level	< 10%	65	200							² Canal Towpath used by 150 pedestrians daily ³ Footpath No 9 60 pedestrians daily
	10 < 20%	250	100	N/A	N/A	N/A	N/A	Footpath No 9 ³	Town Common Broughton Hospital	
	20 < 30%	45	0					Canal ²		
	30 < 40%	39	0					Towpath		
	>= 40%									
L _{A10 18h} dB										
Decrease in Noise Level	1 < 3	75	0	0	0	0	0	Town Common Ambridge School		Ambridge School has 250 pupils ⁴ Broughton Hospital has 250 beds
	3 < 5	300	0	9	0	1	0	Broughton School		
	5 < 10	266	0	0	0	0	0	Hospital		
	10 < 15	138	0	0	0	0	0			
	>= 15	0	0	0	0	0	0			
L _{A10 18h} dB										
Decrease in Nuisance Level	< 10%	125								
	10 < 20%	325								
	20 < 30%	179	N/A	N/A	N/A	N/A	N/A			
	30 < 40%	150								
	>= 40%									

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Table 1

9. FURTHER READING

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- 9.5 LANGDON F J AND I D GRIFFITHS (1982). Subjective effects of traffic noise exposure, II : Comparison of noise indices, response scales, and the effects of changes in noise level. *Journal of Sound and Vibration*, 83(2), 171-180.
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- 9.11 Memorandum on the Noise Insulation (Scotland) Regulations 1975 - HMSO
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- 9.22 MORTON-WILLIAMS J, B HEDGES and E FERNANDO (1978). Road Traffic and the Environment. Social and Community Planning Research.
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1. BACKGROUND TO THE METHOD OF ESTIMATING CHANGES IN TRAFFIC NOISE NUISANCE

1.1 Most of the information on the relation between traffic noise and perceived traffic noise nuisance comes from studies in which the noise exposure has been fairly stable, with no abrupt change having taken place. There have been many such studies, and while the rate of change in nuisance with change in noise tends to be fairly consistent across all surveys, the level of nuisance at any given noise level tends to vary from survey to survey. For this reason Figure 2 shows a curve derived from the combined data of a number of these steady-state surveys (Morton-Williams, Hedges and Fernando, 1978, Watts, 1984 and Huddart, 1994). The earlier version (June 1993) of this document used the steady state relationship from one single national survey (Morton-Williams et al 1978). The composite curve differs from this and should be more reliable.

1.2 Some studies have measured changes in perceived noise nuisance associated with abrupt changes in traffic exposure (Griffiths and Raw, 1986; Mackie and Davies, 1981; Huddart and Baughan, 1993, Huddart and Baughan 1994). These studies have found nuisance ratings change more than would be predicted from a "steady-state" relation such as that shown in Figure 2. The possible explanations for this excess change in nuisance are complex, and are discussed fully by Huddart and Baughan (1994). However, the excess appears to reflect a real change in nuisance that persists for several years at least. The change in nuisance ratings in these situations can be estimated from Figure 3. This curve was based on "before" and "after" studies at 14 sites in England (Huddart and Baughan, 1994), supplemented by data from 7 sites studies by Griffiths and Raw (1986). The change in nuisance was measured on a seven-point satisfaction/dissatisfaction scale and transformed to percentage very much or quite a lot bothered using a relationship between the two scales derived from TRL steady-state surveys (see Chapter 3 Paragraph 3.4). However, an adjustment was applied to the "decrease" part of the curve, as described below.

1.3 Huddart and Baughan (1994) found that ratings of traffic noise nuisance before a decrease in traffic were significantly higher than those measured under "steady-state" conditions. The question arises

of whether environmental appraisals should include or exclude this component of the observed change in ratings. Two possible explanations of the before/steady-state difference are:

- (i) Steady-state surveys show that at a given level of noise, nuisance varies considerably between sites. If the high nuisance sites tend to be the ones chosen for remedial action, "before change" nuisance will indeed tend to be higher than steady state nuisance at the same noise level. This explanation would imply that the effect is a real one, and should be taken into account in appraisals provided the scheme being appraised came forward in the same way as the schemes covered by the research surveys.

Expectations and publicity associated with the forthcoming change may sensitise people to traffic nuisance. This explanation would mean that before surveys would give an inflated estimate of the underlying level of nuisance, and that the appraisal should be based on the difference between the steady-state and after levels of nuisance.

Huddart and Baughan argue that both the above effects are likely to be operating, but that the first is probably the more powerful. This implies that at least part of the difference between before and steady-state nuisance should be included in appraisals. However, problems arise when an attempt is made to build this idea into a practical appraisal method. For example, it is difficult to specify exactly when the current level of nuisance should be estimated from the steady-state relationship, and when the "before" relationship should be used instead.

1.4 It has therefore been decided to exclude the before/steady-state difference from the appraisal

method described here. The effect of this is probably to tend to underestimate the environmental benefits arising from reductions in traffic noise.

1.5 Nuisance ratings before an increase in noise do not differ significantly from the "steady-state" ratings. Therefore no adjustment was required for increase in traffic noise.

1.6 Once the adjustment for decreases in noise has been made, the relationship between change in noise and change in nuisance was found to be very similar for increase sites and decrease sites. Figure 3 therefore shows a single curve applying to both increases and decreases.

1.7 Research indicates that the large nuisance changes observed in before and after studies are not simply short term effects. Griffiths and Raw (1989) found "after" levels of nuisance to differ from "steady-state" levels at seven and nine years after the change in traffic noise exposure. What happens to nuisance levels in the longer term is uncertain. They may move slowly back towards those which would have been predicted from the "steady-state" relation between noise exposure and nuisance. The appraisal method described in this advice assumes that this does happen, and that the nuisance 15 years after a scheme is opened can be estimated from the "steady-state" relationship. One reason for expecting this is that people who move in after the change in noise may react to the noise in a similar manner to people living at "steady-state" sites. Individuals who experienced the noise change may continue to have a different level of nuisance, but the level of nuisance for the site as a whole may change as more and more of the original population are replaced by new residents.

1.8 The method for assessing traffic noise nuisance described in this manual will give estimates for an "average" site. At any individual site the level of nuisance may differ from this "average" estimate.

2. METHOD OF ESTIMATING NOISE NUISANCE CHANGES: WORKED EXAMPLES

2.1 The method for estimating changes in traffic noise nuisance was described in section 5.10. Worked examples are given below.

2.2 Example 1. Do minimum

- (i) At the current noise level of 68.2 dB $L_{A10, 18h}$ 29 per cent of people are bothered by traffic noise (Figure 2).
- (ii) In the 15th year the noise level is predicted to rise to 70.1 dB $L_{A10, 18h}$, when 34 per cent will be bothered by traffic noise (Figure 2).
- (iii) There will therefore be an increase of 5 percentage points, in the number of people bothered, and this value should be entered in Table 1.
- (iii) By the 15th year, the noise is predicted to rise by 1.2 dB $L_{A10, 18h}$ to 68.3 dB $L_{A10, 18h}$, so the percentage of people bothered is 29 (Figure 2).
- (iv) The highest level of bother is therefore in the 15th year, and the reduction in bother is 13 percent, and this value should be entered in Table 1.

2.3 Example 2. Increases in traffic noise

- (i) At the current noise level of 65.9 dB $L_{A10, 18h}$ 24 per cent of people are bothered by traffic noise (Figure 2).
- (ii) An increase of 3.0 dB $L_{A10, 18h}$ is predicted, so the immediate increase in the percentage of people bothered will be 30 percentage points (Figure 3), so 54 per cent will be bothered.
- (iii) By the 15th year the noise is predicted to rise to by a further 1.0 dB $L_{A10, 18h}$ to 70 dB $L_{A10, 18h}$, so 33 per cent of people will be bothered (Figure 2).
- (iv) The highest level of bother (54 per cent) is therefore immediately after the increase in traffic noise, and the increase in bother to enter in Table 1 will be 30 per cent.

2.4 Example 3. Decreases in traffic noise

- (i) At the current noise level of 73.1 dB $L_{A10, 18h}$ 42 per cent of people will be bothered (Figure 2).
- (ii) A noise reduction of 6.0 dB $L_{A10, 18h}$ to 67.1

3. NUISANCE WHERE TRAFFIC IS NOT FREELY FLOWING

3.1 Langdon (1976) found that at sites where traffic does not flow freely, perceived noise nuisance was only weakly related to existing noise indices. Langdon found the best predictor of noise nuisance at his non free flow sites to be the logarithm of the percentage of heavy vehicles (greater than 1525kg gross weight) in the traffic flow. However, since the surveys were carried out by Langdon in the early 1970s, noise emissions from heavy vehicles have been reduced by stricter controls under the Construction and Use Regulations. In addition, there are difficulties in developing a prediction method based on the number of heavy goods vehicles. It is therefore recommended that Figure 2 is used to estimate noise nuisance when traffic is not freely flowing.