VOLUME 11 ENVIRONMENTAL ASSESSMENT

SECTION 3 ENVIRONMENTAL ASSESSMENT TECHNIQUES

PART 7

HA 213/08

NOISE AND VIBRATION

SUMMARY

This Advice Note provides guidance on the assessment of the impacts that road projects may have on levels of noise and vibration. Where appropriate, this advice may be applied to existing roads.

INSTRUCTIONS FOR USE

1. Remove contents pages from Volume 11 and insert new contents pages dated August 2008.

2. Remove Traffic Noise and Vibration document dated August 1994 from Volume 11, Section 3.

3. Insert new Advice Note HA 213/08 into Volume 11, Section 3.

4. Please archive this sheet as appropriate.

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Noise and Vibration

Summary: This advice note provides guidance on the assessment of impacts that road projects may have upon noise and vibration. Where appropriate, this advice may be applied to existing roads.

REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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Contents

1. INTRODUCTION

General

1.1 This Advice Note provides guidance on the appropriate level of assessment to be used when assessing the noise and vibration impacts arising from all road projects, including new construction, improvements and maintenance.

Noise

1.2 Traffic noise is a general term used to define the noise from traffic using a particular section of road. A traffic stream is made up from a variety of vehicle types which have their own individual noise sources. Close to a road individual vehicles can be distinguished in the traffic stream, but further from the road the influence of individual vehicles is lost and the noise becomes a continuous drone.

1.3 A road project has the potential to cause both increases and decreases in traffic noise on an existing road by altering the traffic composition. In the case of a new road, for example a bypass, a completely new noise source can be created.

1.4 The impact of a project at any location can be reported in terms of changes in absolute noise level. In the UK the standard index used for traffic noise is the $L_{A10,18h}$ level, which is quoted in decibels. A full description of this and other terms used in this document is given in Chapter 7.

1.5 The effect on people from a road project can also be reported in terms of nuisance or annoyance. The World Health Organisation (WHO) defined annoyance as 'a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them' (Ref 32). This displeasure can be caused by the overall level of noise or by a change in noise level. The WHO also provide guideline values for noise levels for specific environments and times of the day.

1.6 The assessment of nuisance in this document is based on the average percentage of people who were interviewed at home and had expressed a considerable degree of annoyance at the level of external noise. This measure of community annoyance has been correlated with the standard index used for traffic noise ($L_{A10,18h}$). It should be noted that this definition of nuisance is not necessarily the same as that used in some statutory documents.

1.7 The construction process of a project also has the potential to cause noise impacts. The impact of construction activities is usually reported in terms of changes in absolute noise level using the L_{Aeq} index, although the maximum noise level from any one activity may also be assessed.

Vibration

1.8 A road project also has the potential to cause annoyance and physical damage through vibration. Vibration is a low frequency disturbance producing physical movement in buildings and their occupants. These impacts can happen during the operation of an existing or new road, and also during the construction of a new road. Vibration is usually measured in terms of Peak Particle Velocity, or PPV, which is measured in terms of movement in mm/s.

Legislative Framework

1.9 For any new project there are two main areas of current UK legislation that need to be considered in relation to noise and vibration during the whole project life. The first of these areas is legislation which provides a means to redress the adverse impacts of traffic noise and vibration resulting from the use of new and improved roads on both land and people. The second area of legislation provides a means to redress the adverse impacts of construction noise and vibration resulting from the construction methods used in road projects.

New and Improved Roads

Land Compensation Act 1973
Land Compensation (Scotland) Act 1973

1.10 Part I of the Land Compensation Act provides a means by which compensation can be paid to owners of land or property which has experienced a loss in value caused by the use of public works, such as new or improved roads. Noise and vibration are two of the factors which would be considered in any claims for compensation, but the claim must consider all changes and effects, including betterment.

1.11 Claims can be made under Part I of the Act from 1 to 7 years after the opening of a road project. However, consideration of the likely extent of claims may be made during detailed design following the completion of statutory processes.

The Noise Insulation Regulations 1975 (as amended 1988)
The Noise Insulation (Scotland) Regulations 1975

1.12 The Noise Insulation Regulations were made under Part II of the Land Compensation Act 1973 and the Noise Insulation (Scotland) Regulations 1975 made under the Land Compensation (Scotland) Act 1973.

1.13 Regulation 3 imposes a duty on authorities to provide, or make a grant towards the installation of, noise insulation at eligible buildings. This is subject to meeting certain criteria given in the relevant Regulations.

1.14 Regulation 4 provides authorities with discretionary powers to provide noise insulation at other buildings, in situations where existing carriageways are altered, such as additional lanes provided. Advice on the use of this discretionary power should be sought from the Overseeing Organisation.

The Highways Noise Payments and Movable Homes (England) Regulations 2000
The Highways Noise Payments (Movable Homes) (Wales) Regulations 2001

1.15 The Highways Noise Payments and Movable Homes (England) Regulations 2000 and The Highways Noise Payments (Movable Homes) (Wales) Regulations 2001, provide highway authorities with a discretionary power to provide a noise payment where new roads are to be constructed or existing ones altered. The relevant regulations set out the criteria which should be applied in assessing eligibility for making such payments. Advice on the use of this discretionary power should be sought from the Overseeing Organisation. It is noted that there is no similar Regulation in Scotland.

Construction

The Noise Insulation Regulations 1975 (as amended 1988)
The Noise Insulation (Scotland) Regulations 1975

1.16 Regulation 5 provides relevant authorities with discretionary powers to provide noise insulation at dwellings to reduce the impact of construction noise. Advice on the use of this discretionary power should be sought from the Overseeing Organisation.

Control of Pollution Act 1974

1.17 The Control of Pollution Act 1974 Section 61 sets out procedures for those undertaking works to obtain 'Prior Consent' for construction works within agreed noise limits.

1.18 Applications for such consent are made to the relevant local authority and should contain a method statement of the works and the steps to be taken to minimise noise. Under Section 60 of the Act, the local authority has powers to attach conditions to any consent, limit or qualify any consent to allow for changes and limit the duration of any consents. It should be noted that although it is generally for those undertaking the works to decide whether or not to seek such consent, this is also dependent on the custom and practice of the local authority. Some local authorities request demonstration of best practicable means rather than formal "Prior Consent" applications.

1.19 For the control of noise and vibration at construction sites, BS5228: 1997 (Ref 8) (Noise and Vibration Control on Construction and Open Sites Part 1: Code of Practice for Basic Information and Procedures for Noise and Vibration Control) provides guidance for predicting construction noise and also provides advice on noise and vibration control techniques.

Environmental Protection Act 1990

1.20 Under Part III of the Environmental Protection Act 1990 local authorities have a duty to investigate noise complaints from premises (land and buildings) and vehicles, machinery or equipment in the street. It does not apply to road traffic noise but may be applicable to some construction activities. The Noise and Statutory Nuisance Act 1993 amended Part III of the Environmental Protection Act 1990 by placing additional definitions in the list of statutory nuisances in Section 79 of the Environmental Protection Act. The definitions relate to nuisance caused by vehicles, machinery and equipment in the road.

1.21 If a local authority's Environmental Health Officer is satisfied that a complaint amounts to a statutory nuisance then the authority must serve an abatement notice on the person responsible or in certain cases the owner or occupier of the property. The notice could require that the noise or nuisance must be stopped altogether or limited to certain times of the day.

Other Legislation

The Environmental Noise (England) Regulations 2006
The Environmental Noise (Northern Ireland) Regulations 2006
The Environmental Noise (Scotland) Regulations 2006
The Environmental Noise (Wales) Regulations 2006

1.22 Environmental Noise Regulations have been introduced into the UK to implement the Assessment and Management of Environmental Noise Directive 2002/49/EC. This Directive relates to the assessment and management of environmental noise in EU member states. At the time of publication and in the future, it is expected that Noise Action Plans and additional guidance may be available to Designers that might need to be taken into account during the assessment of road projects.

2. POTENTIAL IMPACTS

Temporary Impacts – Noise and Vibration

2.1 Temporary noise and vibration impacts are normally those that occur between the start of advance works and the end of the project construction period. The term 'disruption due to construction' is commonly used to describe such temporary impacts which occur on both people and the natural environment. In addition to the impacts due to the construction of the road project itself, disruption can arise from advance works, for example to divert utilities, and these works may extend well beyond the road construction site. Where material needs to be transported to or from the construction site, the impacts of the additional heavy traffic along access routes should be assessed.

2.2 Although construction-related impacts are temporary, they may nevertheless be significant. Typical construction impacts might include a localised increase in noise, vibration, dust and dirt, and a loss of amenity due to the presence of heavy construction traffic. Those affected can include people in their homes or places of work, people visiting shopping centres or community facilities and those using public rights of way.

2.3 Ground-borne vibration caused by the activities of heavy construction plant such as bulldozers, scrapers and dump trucks can become perceptible in dwellings and cause nuisance (Ref 20). But the most significant source of noise and ground borne vibration is likely to be piling operations. People often express concern that any vibrations they feel will cause structural damage to their dwelling. However, it has been shown that vibrations that can be felt indoors and which often cause anxiety on the part of occupants are an order of magnitude smaller than would be needed to activate pre-existing strains and cause cracks to propagate. It should be borne in mind that superficial cracks in plaster around openings such as doors and windows often appear during the life of a building and are skimmed and painted over during the course of decoration.

2.4 As there is an expectation that disruption due to construction is a temporary phenomenon, the area in which it is considered to be a nuisance is generally more localised than where the impacts of the road project are likely to be a cause of concern once it has opened to traffic. It has been shown (Ref 3) that the impact of construction nuisance in one form or another, diminishes rapidly with distance.

Permanent Impacts – Noise

2.5 The noise arising from a stream of traffic has two main components. The first component is generated by the engine, exhaust and transmission systems of vehicles and is the dominant source of noise when traffic is travelling at fairly low speeds, or in a low gear. Engine noise from heavy vehicles is commonly the dominant source of low frequency noise. Engine and exhaust noise levels are closely related to engine speed, and transmission noise depends more on gearing than on vehicle speed.

2.6 The second component of traffic noise is generated by the interaction of tyres with the road surface and this is the dominant noise source when traffic is flowing freely at moderate to high speeds. Tyre noise contributes a significant proportion of high frequency noise, especially in wet weather. Tyre noise levels depend on the tyre tread pattern and the road surface roughness, but always increase with vehicle speed in this speed range.

2.7 The noise level from a stream of traffic is an aggregate of the noise emitted by many vehicles, propagated over a distance which varies as the vehicles pass along the road. For a continuous flow of traffic, it is generally reasonable to model this complex source as a single line with uniform emission characteristics, from which the average noise level at a specified distance can be estimated.

2.8 The main factors influencing the noise level close to a road from freely flowing traffic is the traffic volume, speed and composition (% heavy vehicles), and the road gradient and surface characteristics. At a more distant reception point the noise level is attenuated by a number of additional factors, including the distance from the noise source, the nature of the intervening ground surface and the presence of obstructions.

2.9 The total noise level from several sources cannot be combined by simply adding them together since noise levels are calculated as a function of the logarithm of sound pressure. A procedure for combining traffic noise levels is described in the Technical Memorandum Calculation of Road Traffic Noise (CRTN) (Ref 9), which provides a graphical illustration of how the stronger of two sources will have a dominant effect.

2.10 It is widely believed that a given level of traffic noise is more annoying at times when people are resting, especially at night. Historically, the fact that there is much less traffic at night than during the day has allowed assessment on the basis of flows over a restricted number of hours in the day to be regarded as fairly representative. However, the increasing use of strategic networks by long distance goods traffic during these periods of lower flow has the potential to increase the level of noise and the perception of nuisance into nighttime periods.

2.11 Care is needed when assessing a project which may result in adverse noise impacts during the night. While traffic levels and their resultant noise impacts are lower at night than during the day, people tend to be more sensitive to nighttime noise. As noise during the night (11pm to 7am) is only covered slightly by the 18 hour measure used for assessing noise in this document, a qualitative entry or a nighttime noise survey may be required.

Permanent Impacts – Vibration

2.12 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 and these are dominant in the audible frequency range of 50-100 Hz. 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 (Ref 28).

2.13 Vibration can be measured in terms of Peak Particle Velocities, or PPVs (i.e. the maximum speed of movement of a point in the ground during the passage of a source of vibration). For vibration from traffic, a PPV of 0.3 mm/s measured on a floor in the vertical direction is perceptible (Ref 30) and structural damage to buildings can occur when levels are above 10 mm/s (Ref 7). The level of annoyance caused will also depend on building type and usage, However, a building of historic value should not (unless it is structurally unsound) be assumed to be more sensitive (Ref 7).

2.14 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 2 mm/s and typically are below 1 mm/s.

2.15 Normal use of a building such as closing doors, walking on suspended wooden floors and operating domestic appliances can generate similar levels of vibration to that from traffic (Ref 29).

2.16 When considering permanent vibration impacts, special consideration should be given to any areas or features of ecological, archaeological, or historic value within the study area which might need to be protected from adverse impacts of vibration (for example designated heritage sites).

Cumulative Impacts

2.17 The impact from noise and vibration can contribute to the overall cumulative impact of a project in two ways.

2.18 Cumulative impacts from a single project may arise from the combined action of noise or vibration and a number of different environmental topic-specific impacts upon a single receptor/resource. For example, a new road may increase noise at a dwelling, which may also be subject to deterioration in air quality. In addition, earth bunds provided for visual screening may also reduce noise levels at dwellings. Where there is an impact from the project on a single receptor/resource from the combined action of noise and vibration, this should be treated as a cumulative impact.

2.19 Cumulative impacts from different projects in combination with the project may arise from the combined action of a number of different projects, in combination with the project, on a single receptor/ resource. For example, the project may be on a route where further projects are scheduled for opening. These projects may result in changes in traffic flow when each project is completed and hence, increase or decrease noise at dwellings. The traffic flows supplied for the noise and vibration assessment undertaken in accordance with Chapter 3 would normally consider the changes in traffic on the wider network and from other projects. Hence, the information required to assess this type of cumulative impact may be readily available, without the need for a further assessment.

3. PROCEDURE FOR ASSESSING IMPACTS

3.1 The following guidance describes the assessment process for potential noise and vibration impacts arising out of projects involving road construction, operation and maintenance and any mitigation measures that need to be considered.

3.2 The general procedures given in DMRB Volume 11, Section 2 should be followed during the entire assessment process. The latter section includes HA 205/08, which provides a method for the classification of the magnitude of impact and the significance of an effect in order to arrive at an overall level of significance. For the assessment of noise and vibration covered by this document, a classification is only provided for the magnitude of impact, as currently the methodology has not been developed to assign a significance according to both the value of a resource and the magnitude of an impact.

3.3 Specific guidance on what is a significant change in the level of noise or vibration has not been provided in this document as it is considered the Designer is best suited to determine this using professional judgement on a project by project basis.

Assessment of Noise and Vibration Impacts

3.4 The assessment methodology is intended to apply to various phases of planning, design and execution of projects associated with the construction and maintenance of roads. The information derived from this process can also be included within an environmental impact assessment identifying the potential impacts of a project. This process has four discrete phases:

i) **Screening** to determine whether the project has the potential to cause a change to the receiving environment which could result in noise and vibration impacts.

ii) **Scoping** to determine the likely extent of any assessment and to identify sensitive receptors.

iii) **Simple** assessment of noise and vibration impact at dwellings and other sensitive receptors.

iv) **Detailed** assessment of noise and vibration impact at dwellings and other sensitive receptors.

3.5 These phases are generally followed in sequence, although progression may depend on the scale of proposed project, the site and local circumstances. Where sensitive receptors are identified during the scoping phase at which significant noise and vibration impacts are clearly identifiable at such an early stage, it may be appropriate to move directly to a detailed assessment. However, caution should be applied to such an approach as at the scoping stage sufficient data may not always be available to make this decision. Before such an approach is adopted, the Overseeing Organisation should be consulted. In addition, progressing to a detailed assessment may not be necessary, as a simple assessment may be deemed sufficient.

3.6 For the prediction of noise the methodology given in the Calculation of Road Traffic Noise (CRTN) should be used. CRTN was produced in 1975 and updated in 1988 and it is still the standard method for calculating noise from a road in the UK, as described in The Noise Insulation Regulations[1]. Annex 4 of this document provides additional advice and guidance on the use of CRTN.

3.7 For the prediction of vibration from an existing road, the methodology given in Watts 1990 (Ref 28) could be used to predict the maximum vertical PPV at the foundations of a building. However, this methodology requires detailed knowledge of the ground type which may only be available at advanced stages of assessment. If this methodology is to be used for the prediction of expected vibration levels from a new road, then the Overseeing Organisation should first be consulted about the appropriateness of using the method.

3.8 The objective of an assessment is to gain an overall appreciation of the noise and vibration climate both with and without the project, referred to as the Do-Minimum and Do-Something conditions. These conditions need to be assessed for a baseline year of a project and also a future year. The baseline covers the period from initial planning of the project up to the period of construction or operation. The baseline and future assessment years for construction and operational effects should be chosen as follows:

[1] It is noted that the assessment of eligibility in Scotland requires the use of the methodology provided in The Memorandum to Regulations 3 and 6 of the Noise Insulation (Scotland) Regulations.

- For an assessment of noise and vibration from construction, the baseline year is taken as that immediately prior to the start of works. The future assessment year for construction would be a year during the construction period.

- For an assessment of noise and vibration for operation, the baseline year is taken as the opening year of the project. This year is considered to be that which is most representative of the situation immediately before a project opens to traffic. The future assessment year for operation is typically the 15th year after the opening year of the project, but in some circumstances this may occur before the 15th year.

3.9 During the assessment process at simple and detailed stages, comparisons are made between scenarios in the baseline year and the future assessment year. At simple stage, the following two comparisons are made:

(i) Do-Minimum condition in the baseline year against Do-Something condition in the baseline year.

(ii) Do-Minimum condition in the baseline year against Do-Something condition in the future assessment year.

3.10 The above comparisons are made in order to evaluate the impact of the project in the short term (i) and the long term (ii). At the detailed stage, the following two comparisons are made:

(i) Do-Minimum condition in the baseline year against Do-Minimum condition in the future assessment year.

(ii) Do-Minimum condition in the baseline year against Do-Something condition in the future assessment year.

3.11 The above comparisons are made in order to evaluate the impact of the project and assist with the evaluation of entitlement under the relevant Noise Insulation Regulations.

3.12 The magnitude of noise impact from a project should be classified into levels of impact in order to assist with the interpretation of the project. An example classification of magnitude of impacts for traffic noise is given in Table 3.1. The scale given in Table 3.1 may not be applicable to all situations or projects. Factors that can influence the magnitude of impact are, for example, the time of day, the spectral content and the absolute level of the noise source.

Noise change, $L_{A10,18h}$	Magnitude of Impact
0	No change
0.1 – 0.9	Negligible
1 – 2.9	Minor
3 – 4.9	Moderate
5+	Major

Table 3.1 Classification of Magnitude of Noise Impacts

3.13 The level of vibration at dwellings and other sensitive receptors has the potential to increase and decrease. If the level of vibration at a receptor is predicted to rise to above a level of 0.3 mm/s, or an existing level above 0.3 mm/s is predicted to increase, then this should be classed as a change in magnitude of the vibration impact.

3.14 The assessment and design process is iterative and is only completed when either no impacts are predicted or options to avoid, reduce or remedy the potential impact have been exhausted. Where there is an impact resulting from a change in the project design, mitigation or treatment, the project will need to be re-assessed.

3.15 An important part of the assessment process is liaison with stakeholders. This could include the local planning authority, Environmental Health Officers and residents associations, as and when appropriate. Local consultations may serve to acquire existing information and help to identify the appropriate level of assessment and the desired outcomes. This will ultimately save time and costs in developing the project and result in better informed solutions.

3.16 A flow chart has been developed to guide the Designer through the assessment procedure. This does not cover every aspect of the assessment process but indicates the key decisions to be taken at each stage. This flow chart is shown in Figure 3.1.

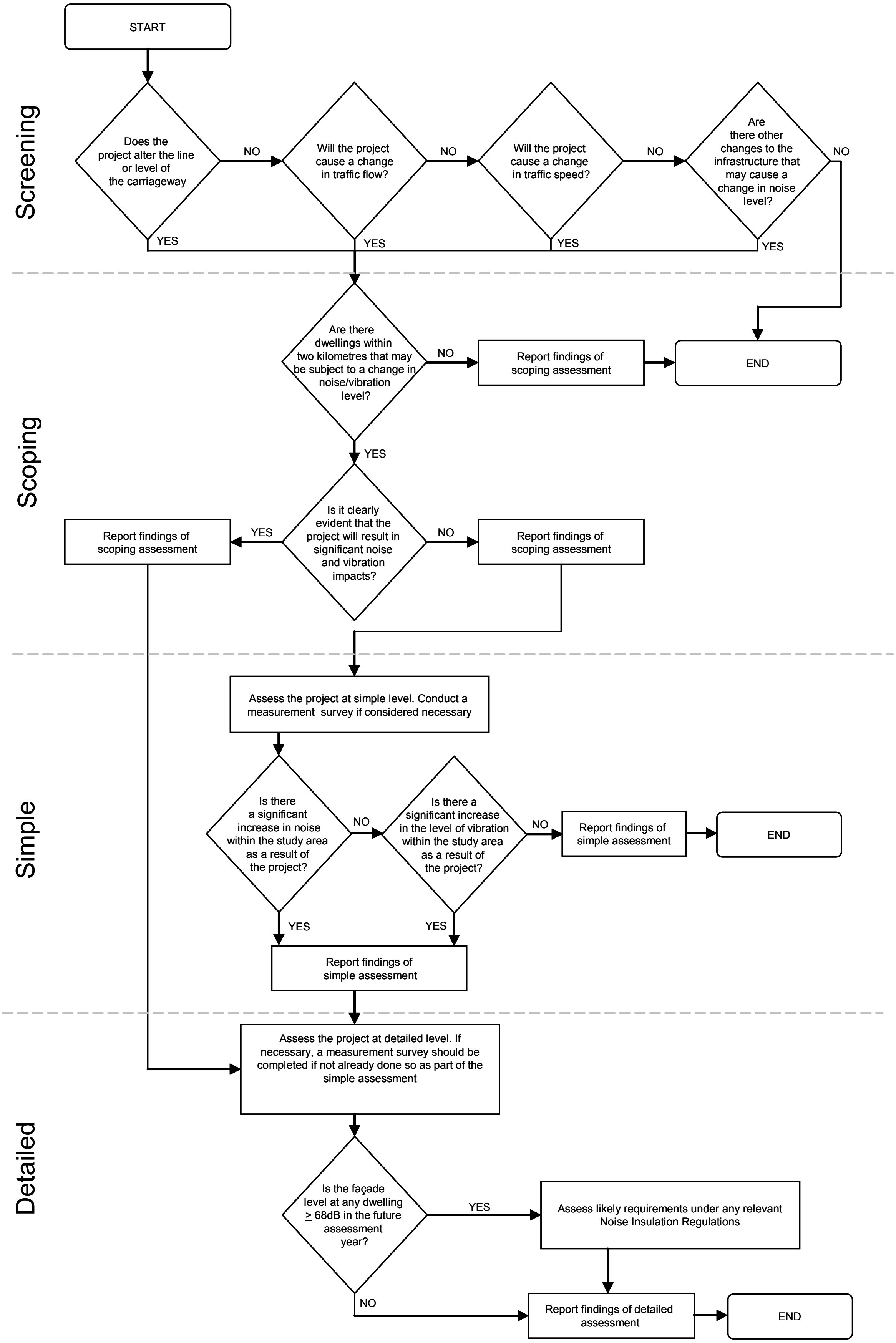

Figure 3.1: Flow Chart for Main Stages of Noise and Vibration Assessment

Screening Assessment

3.17 This is predominately a desk-based exercise to determine the need for a noise and vibration impact assessment for any of the project options being considered. This process includes identifying sensitive receptors and considering any other relevant local information.

3.18 This process also allows stakeholders to register concerns or particular requirements during the period of data collection for this assessment. Those potentially affected will need a full appreciation of the project and the context in which the works are taking place. Depending on the nature of the project, the activities may affect people in their homes or in the vicinity for some or a lot of the time, during day or night, or have impacts on noise sensitive receptors within a wider area.

3.19 As a general rule, an assessment will be required where there is a potential for road construction, maintenance or operation to affect the quality of life or the local environment as the result of noise or vibration.

3.20 The objective of assessment at this level is to gather sufficient data to provide an appreciation of the likely noise and vibration consequences associated with the project identified by the Designer and agreed with the Overseeing Organisation. Any option that could involve significant disruption due to the proximity to population centres, or the possible need for tunnelling, bridgeworks or other intrusive construction processes, should be identified. At this stage of the assessment a site visit is likely to be appropriate.

3.21 The Designer should identify whether any of the following conditions are met:

i) the project alters the alignment of any existing carriageways. This would include new sections of road, additional junctions and slip roads, and hence could result in the introduction of a new noise or vibration source, or a change to noise or vibration levels from an existing road source;

ii) traffic volumes on the existing roads or new routes will increase by at least 25% or decrease by 20% either during construction or when the project is completed. This change in traffic volume is equivalent to a 1 dB(A) change in noise level, which is the minimum change that can be detected by the human ear in the short term (e.g. on opening of a project);

iii) changes in traffic speed or proportion of heavy vehicles on the existing roads or new routes will cause a change in noise level of more than 1 dB(A) either during construction or when the project is completed. Changes in these factors could result in a change in the level of noise or vibration;

iv) any changes to the infrastructure surrounding the road that could, when the project is completed, cause a change in noise level of more than 1 dB(A). This could include such works as resurfacing, bridge building and barrier installation.

3.22 If none of the above criteria indicate that there will be a change in the noise or vibration level, further assessment will not normally be required unless stakeholders put forward a reasoned justification for considering particular local impacts.

3.23 If the assessment continues to scoping then the areas likely to be affected are considered.

Scoping Assessment

3.24 Identify whether there are any dwellings within two kilometres of any part of the project boundary that would be subject to an adverse or beneficial change in noise or vibration. At this stage other sensitive receptors (e.g. community facilities, public rights of ways) or designated areas (e.g. AONB, National Park, SAC, SPA, SSSI) within the study area need to be identified. Any data required by other topic areas to enable them to undertake their environmental assessment on these sensitive receptors should also be identified.

3.25 At this stage the local Environmental Health Officer should be consulted about the existing noise climate. This consultation should include any known sources of complaint, either from traffic or other sources. Any noise constraints arising from Local or National Plans should also be identified at this stage.

3.26 In reporting the findings of the scoping stage the likelihood of noise and vibration impacts occurring should be identified, supported by the reasons leading to this conclusion. The outcome from any necessary consultations should also be reported, together with any particularly sensitive receptors that could be affected by the project.

3.27 The decision whether to move to a simple assessment is based on whether there are any sensitive receptors within two kilometres of any part of the project boundary that would be subject to an adverse or beneficial change in noise or vibration.

3.28 Where it is clearly evident that significant impacts are likely to occur at any sensitive receptor as a result of the project, then it may be appropriate to recommend a move directly to a detailed assessment. However, caution should be applied to such an approach as at the scoping stage sufficient data may not always be available to make this decision. Hence, guidance should always be sought from the Overseeing Organisation before making such a recommendation.

Simple Assessment

3.29 The objective of the simple assessment is to undertake a sufficient assessment to identify the noise and vibration impacts associated with the project.

3.30 This stage is generally a desk-based exercise to determine the impact at known dwellings and other sensitive receptors and to determine whether the project needs to be considered at the detailed level. It is noted that on some occasions not all the data required to complete this assessment will be available. In these instances the assessment should be undertaken with the data available and commentary be added to the report to indicate any limitations in the data or where assumptions have been made.

3.31 The steps to take in the assessment of permanent traffic noise and vibration impacts are:

i) Define the study area. The study area is defined as the area where there are roads that are predicted to be subject to a change in noise level of more than 1 dB(A) as a result of the project on opening. At this stage, before noise calculations have been performed, this change can be determined by an examination of the estimated change in traffic volume. Any existing roads and new routes subject to an increase by at least 25% or decrease by 20% in the baseline year should be considered as affected routes and part of the study area.

ii) For each option, identify those affected routes that are within two kilometres of the project boundary (for urban situations this should be one kilometre). Undertake noise calculations at each dwelling and other sensitive receptors within a maximum distance of 600 metres either side of the centreline of these affected routes. Professional judgement should be used when applying this to situations where the project contains both urban and rural situations. Any deviations from this approach (e.g. where a larger or smaller area for calculations is considered necessary) should be agreed with the Overseeing Organisation.

These calculations should be performed using most likely AAWT traffic growth figures[2] and be undertaken for the Do-Minimum and Do-Something conditions in both the baseline year and the future assessment year. The noise levels calculated should be free-field ($L_{A10,18h}$) at a default height of 1.5 metres above ground level. Further advice should be sought from the Overseeing Organisation where dwellings of over three habitable floors are within the area where noise calculations are to be undertaken, to determine the scope of the assessment for these dwellings. The guidance given in Annex 4 of this document should be consulted before noise calculations are performed.

For dwellings and other sensitive receptors that are within two kilometres of the project boundary but not within 600 metres of an affected route, a qualitative assessment of the noise and vibration impact should be undertaken.

iii) For the affected routes within the study area that are outside the area where noise calculations have been undertaken, an assessment should be undertaken by obtaining the Basic Noise Level (BNL) on these affected routes. A count of the number of dwellings and other sensitive receptors within 50 metres of the centreline of these affected routes should then be undertaken. These BNL and counts should be determined for the Do-Minimum and Do-Something conditions in both the baseline year and the future assessment year.

iv) For each option of the project, prepare a noise difference contour map covering the extent of the noise calculations carried out in (ii) above. The noise levels should be free field $L_{A10,18h}$, calculated at 1.5 metres above ground level. These maps should be prepared for the Do-Minimum condition in the baseline year against the Do-Something condition in the baseline year

2 The figures supplied by the Overseeing Organisation for most likely traffic growth should have been subject to sensitivity testing that reflects any associated uncertainties with the forecast.

and future assessment year. Show the changes in 1 dB intervals with dwellings and other sensitive receptors clearly identified on the maps.

v) Complete an assessment table (shown in Table 3.2) comparing the Do-Minimum condition in the baseline year against the Do-Something condition in the baseline year and the future assessment year. A separate table should be completed for each comparison and also for each option being considered. This table should only include those dwellings and other sensitive receptors where noise calculations have been undertaken in (ii) above.

vi) If it is considered that any other comparisons would further demonstrate the impact of the project, these should also be calculated and reported. For example, although the comparison between Do-Minimum and Do-Something in the future assessment year is not required in the decision making process of whether to move from a simple to detailed assessment, this comparison can sometimes be useful when comparing options or explaining potential impacts to stakeholders.

vii) Consider the need for an assessment of nighttime noise. Such an assessment may be necessary when there are changes in nighttime noise considered to be significant or when the difference between daytime and nighttime levels is within 10 dB(A). The scope and methodology used for any nighttime assessment (or survey) should be defined by the Designer and agreed with the Overseeing Organisation.

viii) Evaluate any potential permanent impacts from traffic induced vibration. This assessment should consist of an estimation of any dwellings and other sensitive receptors that may by subject to noticeable levels of vibration.

Option/Comparison:				
Change in noise level, $L_{A10,18h}$ dB	**Number of dwellings subject to a change in noise level**		**Number of other sensitive receptors subject to a change in noise level**	
	Increase in noise level	**Decrease in noise level**	**Increase in noise level**	**Decrease in noise level**
0				
0.1 – 0.9				
1 – 2.9				
3 – 4.9				
5 +				
Total				

Table 3.2: Simple Assessment Table

3.32 Any dwellings or other sensitive receptors in the category showing a change of more than 5 dB should be described further (e.g. exact magnitude of change, location) in the report for the simple assessment.

3.33 The category for ‘No change’ is included in order to account for every dwelling within the area in which noise calculations have been undertaken in 3.31 and enable a clearer comparison of options to be undertaken. Including all dwellings will also assist with traceability if further levels of the assessment process are undertaken by a different Designer. For a similar reason, a row indicating the total number of dwellings experiencing changes in noise level should also be included in Table 3.2.

3.34 Evaluate any potential temporary noise and vibration impacts. This should consist of identifying maintenance or construction activities that are likely to take place and assess the impact (including duration) on people, dwellings and other sensitive receptors.

3.35 Evaluate any cumulative noise and vibration impacts. This should include of identifying where impacts are expected from the combined action of noise and/or vibration with other environmental topic-specific impacts upon people, dwellings or other sensitive receptors. This may also include identifying where impacts are likely to occur due to the combined action of noise and vibration on receptors. Cumulative impacts expected as a result of the combined action of different projects should also be evaluated.

Reporting

3.36 The report for the simple assessment should consider all options and describe both the permanent and temporary noise and vibration impacts at dwellings and other sensitive receptors. This should include the reporting of quantitative impacts as recorded in Table 3.2, as well as a quantitative or qualitative assessment of the change in BNL and counts of dwellings and other sensitive receptors. A description of the cumulative noise and vibration impacts identified should also be included in the report.

3.37 For dwellings and other sensitive receptors that are within two kilometres of the project boundary but not within 600 metres of an affected route, a qualitative assessment should be reported.

3.38 The overall magnitude of the noise impact from the project should also be reported, using the suggested classification presented in Table 3.1. This should be reported for both the short term (comparing permanent noise impacts for the Do-Something condition in the baseline year with the Do-Minimum condition in the baseline year) and long term (comparing permanent noise impacts for the Do-Something condition in the future assessment year with the Do-Minimum condition in the baseline year). Also included in the report, if applicable, should be an assessment of likely nighttime noise impacts.

3.39 If any dwellings or other sensitive receptors are considered to be subject to a noticeable level of vibration from a new road then this should also be reported.

3.40 Any limitations in the data used or assumptions made during the assessment process should also be reported.

3.41 The decision on whether to proceed to a detailed assessment is based on the impact at dwellings. If any of the criteria given below is met then the Designer should proceed to a detailed assessment for all options still being considered.

i) an increase in noise level of 1 dB(A) or more at any dwelling within the study area as a result of the project in the baseline year;

ii) an increase in noise of 3 dB(A) or more at any dwelling within the study area during the first 15 years as a result of the project; or

iii) the level of vibration at a dwelling is predicted to rise above a level of 0.3 mm/s, or an existing level above 0.3 mm/s is predicted to increase.

3.42 A change of 1 dB(A) in the short-term (e.g. when a project is opened) is the smallest that is considered perceptible. In the long-term, a 3 dB(A) change is considered perceptible, and such an increase should be mitigated if possible. A predicted increase in the level of vibration at any receptor should also be evaluated further and if possible mitigated.

Detailed Assessment

3.43 This level of assessment is generally a desk-based exercise, supplemented with site-collected information needed to inform a quantitative assessment. At this level there will be close consultation with stakeholders and also it will normally involve a noise measurement survey. Disruption due to construction activities will also need to be taken into account by the Designer at this stage.

3.44 This stage of assessment is primarily concerned with the impact at dwellings, with the assessment from the simple stage for other sensitive receptors being updated if necessary. If a project has moved directly from scoping to detailed, an assessment of the noise impact at other sensitive receptors will need to be undertaken. This should now be undertaken to the level required for a simple assessment, but included in the report for a detailed assessment.

Permanent Traffic Noise Impacts

3.45 The steps to take at this stage are:

i) The study area identified for the simple assessment should be refined following any changes in the design of the option. If no simple assessment has been undertaken, then the guidance provided in 3.31(i) should be used to define an appropriate study area. Noise calculations should be undertaken in an area as described in 3.31(ii). At this stage of assessment the calculations must be undertaken out to 600 metres. The noise levels calculated at dwellings should be façade levels and calculated in $L_{A10,18h}$ at a default height of 1.5 metres above ground level. For dwellings with a first floor, the noise level should be calculated at 4 metres above ground level. Further advice should be sought from the Overseeing Organisation where dwellings of over three habitable floors are within the area where noise calculations are to be undertaken. Calculations should be undertaken for Do-Minimum and Do-Something conditions in the baseline year and the future assessment year. The guidance given in Annex 4 of this document should be consulted before noise calculations are performed.

ii) The assessment should classify dwellings according to their façade noise levels, in 3 dB bands between 47.5 dB(A) and 83.5 dB(A), with additional categories for those with noise levels below 47.5 dB(A) and those with noise levels above 83.5 dB(A). For each ambient noise band, all dwellings where calculations have been undertaken in (i) above should be classified in the categories given in the Table 3.3. A separate table should be completed for each of the following comparisons:

1) Do-Minimum condition in baseline year against Do-Minimum condition in the future assessment year,

2) Do-Minimum condition in the baseline year against Do-Something condition in the future assessment year.

iii) For dwellings and other sensitive receptors that are within two kilometres of the project boundary but not within 600 metres of an affected route, a qualitative assessment of the noise and vibration impact should be undertaken.

iv) For the affected routes within the study area that are outside the area where noise calculations have been undertaken, an assessment using the same procedure as that described in 3.31(iii) should be undertaken. These assessments should be carried out in the Do-Minimum and Do-Something conditions in both the baseline year and the future assessment year

v) Consider the need for an assessment of nighttime noise. Such an assessment may be necessary when there are changes in nighttime noise considered to be significant or when the difference between daytime and nighttime levels is within 10 dB(A). The scope and methodology used for any nighttime assessment (or survey) should be defined by the Designer and agreed with the Overseeing Organisation.

vi) If it is considered by the Designer that any other comparisons would further demonstrate the impact of the project, these should also be calculated and subsequently reported.

vii) The Table for a simple assessment showing the change in noise level at other sensitive receptors should be either completed or updated. This should be undertaken using the guidance for a simple assessment (e.g. using free field levels).

3.46 The assessment should show predicted noise changes calculated to the nearest 0.1 dB(A) and agreed mitigation should be taken into account (excluding any statutory noise insulation).

3.47 Where a dwelling is predicted to experience an increase in noise level on one façade and a decrease on another façade, the worst case in terms of change in noise level should be reported in the assessment table. This can often happen in projects involving a bypass.

3.48 Although noise calculations are based on future traffic flows, the impact of the changes can only be recorded for people currently living and using facilities in the affected area. Where planning permission for residential development or other sensitive receptors has been granted but not implemented, the potential impacts on these additional buildings should be reported separately.

Permanent Traffic Nuisance Impacts

3.49 The steps to take at this stage are:

i) Calculate the change in nuisance for all dwellings at which noise calculations have been carried out in accordance with 3.45(i) above. The increases or decreases in the number of people bothered by noise should be tabulated in <10 percentage points, 10<20 percentage points, 20<30 percentage points, 30<40 percentage points, or >40 percentage points. The following assessments should be undertaken:

1) Do-Minimum condition in baseline year against Do-Minimum condition in the future assessment year,

2) Do-Minimum condition in the baseline year against Do-Something condition in the future assessment year.

ii) These comparisons are undertaken in order to compare the Do-Minimum condition in the baseline year with the two possible conditions that are available in the future assessment year. All calculations should be based on the highest nuisance levels calculated during the first 15 years after opening. Guidance on the calculation of nuisance is given in Annex 3. The results from this assessment should be included in the detailed assessment Table.

3.50 When the project will cause increases in noise, the highest level of nuisance experienced will usually be soon after opening as estimated using Figure A3.2. For decreases in noise level as a result of the project, the highest nuisance experienced during the first 15 years after opening will usually be that in the 15th year, estimated from Figure A3.1.

3.51 If only gradual changes in traffic noise are likely (for example, in the Do-Minimum situation), the 'steady state' curve should be used to estimate current and future nuisance levels (i.e. percentage bothered). 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 value of nuisance in the Do-Minimum baseline year condition.

3.52 **Where there are predicted to be increases in traffic noise in the baseline year as a result of the project**, the nuisance in the Do-Minimum condition is first estimated from the steady state curve. The immediate increase in nuisance as a result of the project is then estimated from the short term response curve, and the new level of nuisance is the sum of these two values. The level of nuisance in the future assessment year is then estimated from the steady state curve. The level to be reported in the assessment Table is the highest level in terms of increase in nuisance between the two conditions (i.e. Do-Minimum in the baseline year against Do-Something in the baseline year; and Do-Minimum in the baseline year against Do-Something in the 15th year).

3.53 **Where there are predicted to be decreases in traffic noise in the baseline year as a result of the project**, the level of nuisance in the Do-Minimum condition is first estimated from the steady state curve. The change in nuisance based on the highest nuisance in the first 15 years after opening is again required. Generally this will be the 15th year value from the 'steady state' curve, hence the value of nuisance in the future assessment year is estimated from the steady state curve. The change in nuisance can be then be estimated by subtraction, using values from the 'steady state' curve (i.e. Do-Something in 15th year minus Do-Minimum in the baseline year). 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 project opens. The immediate decrease as a result of the project is estimated from the short term response curve. The new nuisance level is that in the Do-Minimum condition minus the decrease. However, if this reports a negative value then a value of zero (per cent of people bothered) should be assumed.

3.54 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 the short term response curve, is ignored. For a project where this benefit is thought to be particularly important, a special note should be made in the assessment table, specifying the size of the immediate decrease in nuisance.

Permanent Traffic Induced Vibration Impacts

3.55 Where appropriate, an assessment of traffic-induced vibration should be undertaken. Guidance on assessing the numbers of people bothered by airborne vibration is provided in Annex 3. If ground-borne vibration on existing routes is considered to be a potential problem, calculations or measurements of vibration at the foundations of typical buildings considered to be at high risk may be taken in order to establish whether increasing vibration levels would be likely to exceed the threshold of perception. Based on these results at a sample of dwellings, an estimate can be made of the number of buildings likely to be exposed to perceptible vibrations along the affected route. This will only apply in rare cases where, for example, heavy construction traffic is expected to pass near to buildings. The number of buildings and an estimate of peak vibration levels (PPVs) should be included in the assessment.

Project/Option:																
Change in noise/nuisance level		**Number of dwellings (façade level noise band $L_{A10,18h}$ dB for Do-Minimum condition in the baseline year)**														
		Total	**< 47.5**	**47.5 - 50.4**	**50.5 - 53.4**	**53.5 - 56.4**	**56.5 - 59.4**	**59.5 - 62.4**	**62.5 - 65.4**	**65.5 - 68.4**	**68.5 - 71.4**	**71.5 - 74.4**	**74.5 - 77.4**	**77.5 - 80.4**	**80.5 - 83.4**	**≥ 83.5**
Increase in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9															
	1 – 2.9															
	3 - 4.9															
	5 +															
Decrease in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9															
	1 – 2.9															
	3 - 4.9															
	5 +															
Increase in nuisance level	< 10%															
	10 < 20%															
	20 < 30%															
	30 < 40%															
	≥ 40%															
Decrease in nuisance level	< 10%															
	10 < 20%															
	20 < 30%															
	30 < 40%															
	≥ 40%															

Table 3.3: Detailed Assessment Summary Table

Temporary Noise and Vibration Impacts

3.56 For most cases, at this stage a detailed assessment of possible disruption at the works site will consist largely of updating or adding to the simple assessment for the project. The steps to take are:

i) Confirm the estimated number of dwellings or other sensitive receptors within the study area for the project, and highlight any that are particularly sensitive to disruption.

ii) Confirm the presence of areas or features of ecological or archaeological value within the study area of the project that might need to be protected from adverse impacts.

iii) Identify any construction operations which could have a significant impact – for example, the scale of earth movements within the construction site, the storage and treatment of surplus material before it can be removed from the works site (such as wet peat which needs to be dried out and which may need to cover a large area of ground), the extent of special operations such as piling, bridgeworks or tunnelling, and the likelihood of night-time working.

iv) Assess the extent and duration of potential impacts, taking account of proposed mitigation agreed with the Overseeing Organisation, such as the early provision of environmental barriers or noise insulation, restrictions on noise levels or any other special conditions to be written into the contract documents.

3.57 As the earthworks design for the project develops, an estimate should be made of the likely quantities of surplus material and borrow associated with the project. Whether a separate assessment of this is required will depend on the quantity of material which needs to be transported to or from the road construction site, and the availability of borrow or surplus fill capacity in the locality.

3.58 The type of information to be reported should include a general indication of the size and location of the potential pits or disposal sites and their distance from the road project, the existing land use, an estimate of the number of dwellings within 100 metres (interpreted flexibly) and possible disruption to them, and an indication of any other adverse impacts (e.g. on the ecology or agriculture).

Cumulative Impacts

3.59 An assessment of cumulative noise and vibration impacts should be undertaken. This should include identifying where impacts are expected from the combined action of noise or vibration with other environmental topic-specific impacts upon people, dwellings or other sensitive receptors. This should also include identifying where impacts are likely to occur due to the combined action of noise and vibration on receptors. Cumulative impacts expected as a result of the combined action of different projects should also be evaluated.

Reporting

3.60 The report for the detailed assessment should consider all options and describe both the permanent and temporary noise and vibration impacts at dwellings and other sensitive receptors. This should include the reporting of quantitative impacts as recorded in Table 3.3, as well as a quantitative or qualitative assessment of the change in BNL and counts of dwellings. For the reporting of the change in BNL, the absolute BNL in the Do-Minimum baseline year should also be reported for each affected route. A description of the cumulative noise and vibration impacts identified should also be included in the report.

3.61 The overall magnitude of the noise impact from the project should also be reported, using the suggested classification presented in Table 3.1. This should be reported for both the short term (comparing permanent noise impacts for the Do-Something condition in the baseline year with the Do-Minimum condition in the baseline year) and long term (comparing permanent noise impacts for the Do-Something condition in the future assessment year with the Do-Minimum condition in the baseline year). A description of the noise mitigation included to reduce both temporary and permanent noise and vibration impacts should also be included for each of the options.

3.62 Where there is a prevailing wind direction that could influence the comparison between options or between the Do-Minimum and Do-Something conditions, a qualitative comment on this should also be included. Also included in the report, if applicable, should be an assessment of likely nighttime noise impacts.

3.63 Any limitations in the data used or assumptions made during the assessment process should also be reported.

4. SURVEY OF EXISTING CONDITIONS

Noise

4.1 Conducting a noise measurement survey may be an integral part of the assessment process and would usually be undertaken at detailed level. A noise survey can assist with the understanding of the existing noise level and in explaining the noise climate of a particular area.

4.2 The measurement methodology contained within the Calculation of Road Traffic Noise (CRTN) for measurements is strictly for circumstances when predictions are not possible for the assessment of entitlement under the relevant Noise Insulation Regulations.

4.3 For a noise survey of existing conditions that is used to provide a broad understanding of the noise climate, strict adherence to the measurement methodology contained within CRTN is not always necessary. For example, in circumstances where the noise source is steady, it may be more appropriate to conduct three noise measurements of one hour rather than one measurement over three hours. However, the general guidelines that are contained in CRTN for undertaking measurements should always be followed.

4.4 The number and location of measurement sites is left to the Designer to determine, and will be very much dependant upon the complexity of the project. The number of sites should be appropriate to describe the noise climate in the area of the project. If measurements are conducted at an early stage, sufficient sites should be selected to represent all possible options.

4.5 When selecting measurement sites, the possible need to conduct post completion noise measurements and potential compensation claims should be considered. For example, a road in a rural area may have impacts up to two kilometres away.

4.6 Other guidance documents are available to assist with undertaking noise surveys and the Designer should choose the most appropriate methodology to be used and agreed with the Overseeing Organisation. This will be dependent on the circumstances of the project. Best practice should always be followed and some specific guidance notes are given in Annex 5.

4.7 During the assessment process, measurements should not routinely be compared with calculations for the purpose of predicting changes in noise level. There is currently no methodology available to take account of the potential errors associated with comparing measurements with calculations, especially when the receptor is some distance from the noise source. For situations where it is not possible to undertake calculations in the Do-Minimum situation but it would be possible in the Do-Something situation (e.g. at a receptor with existing low noise levels but a noise source is to be introduced), it may be necessary to compare measurements with calculations.

4.8 At minimum a noise survey report should include a map showing the location of all measurement positions, a description of each position and a table of results (including meteorological conditions) with appropriate commentary for each attended measurement period. An explanation should be given of all the noise sources that contribute to the noise climate at each measurement position. Commentary should also be made of any changes in the noise climate that are expected to occur between the time of the noise survey and the time when the project is planned to open. This could include expected changes in traffic composition or new or intensified usage of existing developments. If any measured noise levels are above any statutory exposure limits or guideline levels then these should be noted in the report and highlighted to the Overseeing Organisation.

Vibration

4.9 If a vibration survey is required, this should be undertaken in accordance with available guidance. The decision on whether to undertake a vibration survey should be based on an assessment of likely impacts, which would be determined by such factors as the distance between the road and sensitive receptors, ground type and road condition. However, the Designer should seek the approval of the Overseeing Organisation before undertaking any ground-borne vibration survey.

4.10 When undertaking measurements the Designer should also, if possible, include an indication of the expected level of vibration from everyday household activities (e.g. the closing of doors).

4.11 In reporting the results from any vibration survey, the Designer should highlight the number of events likely to be above noticeable levels and also consider the likely cause of the events.

5. NOISE AND VIBRATION MITIGATION

5.1 The assessment of noise and vibration should be based on the project with permanent mitigation as agreed by the Overseeing Organisation. Any temporary mitigation measures put in (e.g. environmental barriers during construction) should not be included in the assessment.

5.2 Some examples of possible mitigation techniques are described below. Except where noted, they will help to attenuate both noise and vibration.

i) Horizontal alignment – By moving a route away from residential areas or other sensitive receptors.

ii) Vertical alignment – Keeping a route low within the natural topography to exploit any natural screening and enhancing this by the use of cuttings and, in exceptional circumstances, sub-surface and surface tunnels.

iii) Environmental barriers – These can be in the form of earth mounding or acoustic fencing of various types or a combination of the two. 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 tests show appreciable benefits from the design proposed. The use of reflective and absorptive barriers should also be considered. Further advice on how the assessment should consider such barrier types in the modelling process is given in Annex 4.

iv) Low-noise surfaces – The principal benefit of low-noise surfaces is the reduction in mid and higher frequencies of noise generated by tyres. They are less effective in addressing low frequency noise generated by heavy vehicles that may be perceived as airborne vibration. These also create a relatively smooth running surface that in some cases can help to reduce ground borne vibration.

v) Speed and volume restrictions – The effect of the speed of vehicles on noise level is one of the most fundamental in the noise prediction process. Above 40 km/hr, noise level increases with the speed of the vehicle and a reduction in speed will normally cause a reduction in noise level. In a similar way, the volume of traffic has a direct influence on the noise level.

5.3 The potential benefits of mitigation measures vary widely according to circumstances. For example, environmental barriers can provide reductions of 10 dB or more for well-screened locations relatively close to the source. But at further distances, and especially where the barrier provides only a small deflection of the transmitted sound waves, actual noise reductions may only be 1 or 2 dB. Beyond 200-300 metres, the effects are often zero as ground attenuation becomes the most significant factor. The use of shrubs or trees as a noise barrier is only effective if the foliage is at least 10 metres deep, dense and consistent for the full height of the vegetation (Ref 15).

5.4 The benefits of adjusting alignments are even more difficult to determine without complex calculations; a horizontal realignment can often take advantage of natural screening or provide opportunities to create landscaped features. Lowering a road into cutting may be more attractive than erecting noise barriers and may generate extra fill which can be used for earth mounding to enhance the screening effect.

5.5 Although putting a road into a tunnel will eliminate the noise from the enclosed section, there is potential for reverberant noise to be emitted at either end of the tunnel and increase the noise from traffic on the approaches which may also be exacerbated by reflections between the flanking retaining walls. Noise absorptive surfaces within the entrance of the tunnel and on the retaining walls can help to reduce this if it is a problem.

5.6 Calculation of Road Traffic Noise (CRTN) cannot deal with the effects of partial reflections or with 3D effects and there may be need for a more sophisticated analysis of noise if there are noise sensitive receptors in close proximity to the end of a tunnel. Work has shown that the reflection effects at a tunnel portal are localised, and possibly only noticeable within 100 metres of the portal.

5.7 Reducing the noise and vibration impact from a road is just one of the factors to be considered in design, and conflicts can exist. Careful consideration should be given to cases where such conflict may exist, e.g. an acoustic barrier may introduce unacceptable visual intrusion or safety implications. In addition, any mitigation measure must perform to an acceptable level in traffic, road safety, economic and other environmental terms.

5.8 Noise from construction can be mitigated to a certain extent both under powers conferred by the relevant Land Compensation Act or by imposing contractual working restraints. The Land Compensation Act allows for temporary re-housing when the disruption is of such an extent that continued occupation is not reasonably possible. The Act also permits insulation of eligible buildings against construction noise where that noise seriously affects, for a substantial period of time, the enjoyment of the building. This is independent of any requirement for noise insulation resulting from traffic noise. However, where houses are eligible for insulation from traffic noise, the insulation work could be carried out early enough for the recipients to benefit during the construction period.

5.9 Contractual working restraints are particularly important where the natural environment needs to be protected against potentially adverse impacts caused by particular construction methods. For example, restrictions can be written into the contract documents that prevent the storing of borrow or surplus material in particular areas. Contract conditions can also be used to limit noise from the construction site, to control working hours (especially for potentially disruptive operations), to prevent access to sensitive areas, to restrict construction traffic to suitable haul routes, and to ensure that such routes are cleaned or swept regularly. It is important that contractual working restraints are discussed in advance with the local authority Environmental Health Officer. Monitoring of conditions regarding noise, vibration and dust may be necessary during construction.

5.10 Nuisance from construction vibration can be reduced by the use of specialised equipment. Martin (Ref 21) gives further guidance on mitigation measures to reduce vibration and describes a method of predicting vibration levels. In considering possible methods of mitigating adverse impacts during the construction period, it will be necessary to balance the severity of an impact with its duration. For example, it may be more acceptable if slightly greater disruption occurs over a short period than lesser disruption over an extended period.

6. REFERENCES

Assessment and Management of Environmental Noise Directive 2002/49/EC.

Control of Pollution Act 1974.

Environmental Protection Act 1990.

Land Compensation Act 1973.

Land Compensation (Scotland) Act 1973.

Noise and Statutory Nuisance Act 1993.

The Noise Insulation (Scotland) Regulations 1975.

The Noise Insulation Regulations, 1975 (Amendment 1988).

The Environmental Noise (England) Regulations 2006.

The Environmental Noise (Northern Ireland) Regulations 2006.

The Environmental Noise (Scotland) Regulations 2006.

The Environmental Noise (Wales) Regulations 2006.

The Highways Noise Payments (Movable Homes) (Wales) Regulations 2001.

The Highways Noise Payments and Movable Homes (England) Regulations 2000.

1. Abbott, P.G., 1994. Calculation of traffic noise from widened motorways – Final Report. Unpublished Project Report PR/SE/34/94, Transport Research Laboratory, Crowthorne.

2. Abbott, P.G., 1999. Calculation of road traffic noise – Extending the range of propagation. Unpublished Project Report PR/SE/611/99, Transport Research Laboratory, Crowthorne.

3. Baughan, C.J., 1980. Nuisance from road construction: A study at the A31 Poulner Lane diversion, Ringwood. TRRL Report SR562, Transport and Road Research Laboratory, Crowthorne.

4. Baughan, C.J. and Martin, D.J., 1981. Vibration nuisance from road traffic at fourteen residential sites. TRRL Laboratory Report LR120, Transport and Road Research Laboratory, Crowthorne.

5. Baughan, C.J. and Huddart, L., 1993. Effects of noise changes on residents' nuisance ratings. Proceedings of the 6th international congress on noise as a public health problem. Nice, 5-9 July. Actes inrets 34(2), 585-588.

6. British Board of Agrément, 2004. Guidelines document for the assessment and certification of thin surfacing systems for highways. SG3/05/234. British Board of Agrément, Garston, England.

7. British Standards Institution (1993). Evaluation and measurement for vibration in buildings, Part 2 Guide to damage levels from ground-borne vibration. BS 7385: Part 2: 1993. British Standards Institution, Chiswick.

8. British Standards Institution (1997). Noise and Vibration Control on Construction and Open Sites Part 1: Code of Practice for Basic Information and Procedures for Noise and Vibration Control. BS 5228 Part 1: 1997. British Standards Institution, Chiswick.

9. Department of Transport and Welsh Office (1988). Calculation of Road Traffic Noise. HMSO, London.

10. Fidell, S., 2003. The Schultz curve 25 years later: A research perspective. Journal of the Acoustic Society of America, 114(6) pp3007-3015.

11. Griffiths, I.D. and Raw, G.J., 1986. Community and individual responses to changes in traffic noise exposure. Journal of Sound and Vibration, 111(2), 209-217.

12. Griffiths, I.D. and Raw, G.J., 1989. Adaptation to changes in traffic noise exposure. Journal of Sound and Vibration, 132(2), 331-336.

13. HETA, 2001. Transport Users Benefit Appraisal User Manual, TUBA User Guidance with accompanying TUBA software.

14. Hothersal, D.C., 1983. The reflection of road traffic noise, Journal of Sound and Vibration, Vol 90 part 3 pp399-405.

15 Huddart, L., 1990. The use of vegetation for traffic noise screening. Department for Transport, TRL Research Report RR238. Transport Research Laboratory, Crowthorne.

16. Huddart, L. and Baughan, C.J., 1994. The effects of traffic changes on perceived nuisance. Department of Transport, TRL Research Report RR363. Transport Research Laboratory, Crowthorne.

17. Huddart, L., 1994. The extent of traffic nuisance at different times of the day and night. TRL Unpublished Project Report, Transport Research Laboratory, Crowthorne.

18. Langdon, F.J., 1976. Noise nuisance caused by road traffic in residential areas: parts 1 & 2, Journal of Sound and Vibration, 47(2), 243-282.

19. Mackie, A.M. and Davies, C.H., 1981. Environmental effects of traffic changes. Department of Transport, TRL report LR1015, Transport Research Laboratory, Crowthorne.

20. Martin, D.J., 1977. Ground vibrations caused by road construction operations. TRL Report SR 328, Transport research Laboratory, Crowthorne.

21. Martin, D.J., 1980. Ground vibrations from impact pile driving during road construction. TRL Report SR544, Transport Research Laboratory, Crowthorne.

22. Miedema, H.M.E., Passchier-Vermeer W and Vos H, 2002. Elements for a position paper on dose effect relationships for nighttime noise, TNO inro Report 2002-59.

23. Morton-Williams, J., Hedges, B. and Fernando, E., 1978. Road traffic and the environment. Social and Community Planning Research.

24. Ng, I.W.K., Wong, S.W.H. and Chiu, C.C., 1993. Prediction and field validation of road traffic noise. Proceedings Institute of Acoustics, Vol.15. Part 8. pp 29-34.

25. Reijnen, M.J.S.M., Veebaas, G. and Foppen, R.P.B., 1995. Predicting the effects of motorway traffic on breeding bird populations. Roads and Hydraulic Engineering Division, Rijkswaterstaat, Netherlands.

26. Rice, C.G. and Morgan, P.A., 1982. A synthesis of studies of noise induced sleep disturbance. Institute of Sound and Vibration Research memorandum 623, University of Southampton.

27. Sagoo, H.S., 1992. Assessment of Noise from traffic on a dual carriageway. Proceedings Euro-noise ’92. Book 3. pp841-848. London.

28. Watts, G.R., 1990. Traffic induced vibration in buildings. TRRL RR246, Transport and Road Research Laboratory, Crowthorne.

29. Watts, G.R., 1984. Vibration nuisance from road traffic – Results of a 50 site survey. TRRL Report LR 1119, Transport and Road Research Laboratory, Crowthorne.

30. Watts, G.R., Harris, G.J. and Layfield, R.E. (1997). Traffic calming: vehicle generated ground-borne vibration alongside speed control cushions and road humps. TRL Report 235. Transport Research Laboratory, Crowthorne.

31. Watts, G.R. and Godfrey, N.S., 1999. Effects on roadside noise levels of sound absorptive materials in noise barriers. Applied Acoustics Vol. 58 pp 385-402. 1999.

32. World Health Organisation, 2000. Guidelines for Community Noise. World Health Organisation, Geneva.

33. Wright, P., Skinner, C.J. and Grimwood, C.J., 2002. The national noise incidence study 2000 (England and Wales). BRE Client Report number 203938f, Building Research Establishment, Garston, Watford.

7. GLOSSARY OF ACOUSTIC AND OTHER TERMS

A-weighting

In addition to its non-linear amplitude response, the human ear has a non-linear frequency response; it is less sensitive at low and high frequencies and most sensitive in the range 1 kHz to 4 kHz (cycles per second). The A-weighting is applied to measured sound pressure levels so that these levels correspond more closely to the subjective response. A-weighted noise levels are often expressed in dB(A).

AAWT

Annual Average Weekday Traffic.

Ambient Noise

Ambient noise is the total sound in a given situation at a given time usually composed of sound from many sources, near and far.

Baseline year

For an assessment of noise and vibration, the baseline year is taken as the opening year of the project.

Basic Noise Level (BNL)

The BNL is a measure of source noise at a reference distance of 10 metres from the nearside carriageway edge. It is determined from obtaining the estimated noise level from the 18 hour flow and then applying corrections for vehicle speed, percentage of heavy vehicles, gradient and road surface.

Calculation of Road Traffic Noise (CRTN)

The technical memorandum issued by the Department of Transport and Welsh Office that describes the procedures for calculating noise from road traffic.

Decibel

This is the unit of measurement used for sound pressure levels and noise levels are usually quoted in decibels (dB). The decibel scale is logarithmic rather than linear. The threshold of hearing is zero decibels while, at the other extreme, the threshold of pain is about 130 decibels. In practice these limits are seldom experienced and typical levels lie within the range of 30 dB(A) (a quiet nighttime level in a bedroom) to 90 dB(A) (at the kerbside of a busy street).

Dwelling

A building used for living purposes. A mobile home used for permanent living should be included in an assessment. If calculations are being conducted for compensation purposes then some mobile homes are dealt with under the Highways Noise Payments and Moveable Homes Regulations.

Facade Sound Level

A facade sound level is that determined 1m in front of the most exposed window or door in a facade. Sound is reflected from hard surfaces in a similar manner to light by a mirror and the effect is to produce a slightly higher (about 2.5 dB) sound level than would occur if the building was not there. For façade levels at dwellings required for this assessment process, the level one metre from the most exposed façade should be calculated with a reflection correction.

Free-Field Sound Level

The sound level which is measured or calculated, in the open, without any reflections from nearby surfaces. For free-field levels at dwellings required for this assessment process, the level one metre from the most exposed façade should be calculated without a reflection correction.

Future assessment year

The future assessment year is the year between baseline and the 15th year where the maximum impact from the project would occur.

L_{A10} index

L_{A10} is the A-weighted sound level in dB that is exceeded 10% of the measurement period. This is the standard index used within the UK to describe traffic noise. From research it has been found that subjective response to road traffic noise is closely linked to higher noise levels experienced and is correlated well with the L_{A10} index.

L_{A90} index

The background noise level is commonly quoted using the L_{A90} index. This is the A-weighted sound level in dB that is exceeded 90% of the measurement period.

$L_{A10,18h}$ index

The $L_{A10,18h}$ noise level is arithmetic mean of all the levels of L_{A10} during the period from 06:00 to 24:00.

L_{Aeq} index

The equivalent continuous sound level L_{Aeq} is the level of a notional steady sound, which at a given position and over a defined period of time, would have the same A-weighted acoustic energy as the fluctuating noise.

L_{Amax} index

The maximum A-weighted level measured during a given time period.

Nuisance

In this document nuisance is intended to generally refer to “bother” or “annoyance” and is not necessarily the same as that used in some statutory documents.

Rural

See Urban

Sensitive receptor

A location which for its proper use or enjoyment requires the absence of noise and vibration. Examples include dwellings, hospitals, schools, parks and public rights of way.

Urban

Land is recognised as urban if it has a minimum area of 20 hectares and if it meets the definition of urban land in the 1991 Census of Key Statistics for Urban and Rural areas. This defines urban land as comprising of:

- Permanent built-up structures
- Transportation corridors
- Transport features
- Mine buildings
- Any area completely surrounded by built up sites.

8. ENQUIRIES

All technical enquiries or comments on this Advice Note should be sent in writing as appropriate to:

Division Director of Network Services – Technical Services Division The Highways Agency City Tower Manchester M1 4BE	D DRYSDALE Division Director of Network Services – Technical Services Division

Director, Major Transport Infrastructure Projects Transport Scotland 8th Floor, Buchanan House 58 Port Dundas Road Glasgow G4 0HF	A C McLAUGHLIN Director, Major Transport Infrastructure Projects

Chief Highway Engineer Transport Wales Welsh Assembly Government Cathays Parks Cardiff CF10 3NQ	M J A PARKER Chief Highway Engineer Transport Wales

Director of Engineering The Department for Regional Development Roads Service Clarence Court 10-18 Adelaide Street Belfast BT2 8GB	R J M CAIRNS Director of Engineering

ANNEX 1 NOISE AND INDICES

Sound

A1.1 Sound is a disturbance propagated through the air as a pressure wave. The fluctuations in atmospheric pressure are detected by the ear and produce the sensation of hearing. The frequency of the pressure wave is converted to pitch and its amplitude to loudness. The human ear can respond to a very wide range of amplitudes and frequencies of sound, although its sensitivity to high frequencies deteriorates with age. Noise is generally considered to be unwanted sound.

A1.2 The response of the hearing system to the amplitude of sound pressure is non-linear and can be characterised by a logarithmic relationship. The relationship is also frequency dependent and an adjustment or weighting is applied to the response of a microphone to different frequency components of a sound in order to produce a scale that better reflects the hearing system. In addition, in order to characterise sounds that fluctuate in intensity, it is necessary to derive a statistic that applies over a period of time.

A1.3 A variety of statistics are used in different circumstances and an explanation of the different noise scales is later. The standard index used to characterise traffic noise in the UK is the average noise level exceeded for 10% of the time between 06:00 and 24:00 on a typical weekday.

A1.4 The human system of hearing is very complex and is capable of analysing specific sound patterns such as speech in the presence of noise. However, background noise can mask the structure of meaningful sounds if it contains a similar range of frequencies as the sound of interest. As background noise levels rise, the effort of concentrating on meaningful sounds becomes greater. Depending on the circumstances, this may lead to a sense of frustration or annoyance, especially if the noise is generated by a source that is outside the individual's control.

A1.5 Very low frequencies of sound may resonate within the chest cavity or with floors, doors and windows and are often perceived as air borne vibration. When experienced within the home, these low frequency effects are sometimes confused with those arising from ground borne vibrations being transmitted through structural foundations.

Units of Measurement

A1.6 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:

> SPL - 20 log (*p/po*) dB where *p* is the sound pressure and *po* the sound pressure at the threshold of hearing.

A1.7 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 130 dB (the threshold of pain). Figure A1.1 gives a broad indication of typical $L_{A10,18h}$ traffic noise levels likely to be encountered at various distances from the road for two different traffic conditions. The first is representative of a heavily trafficked road (about 150,000 vehicles per day) and the second a lighter trafficked road (about 50,000 vehicles per day).

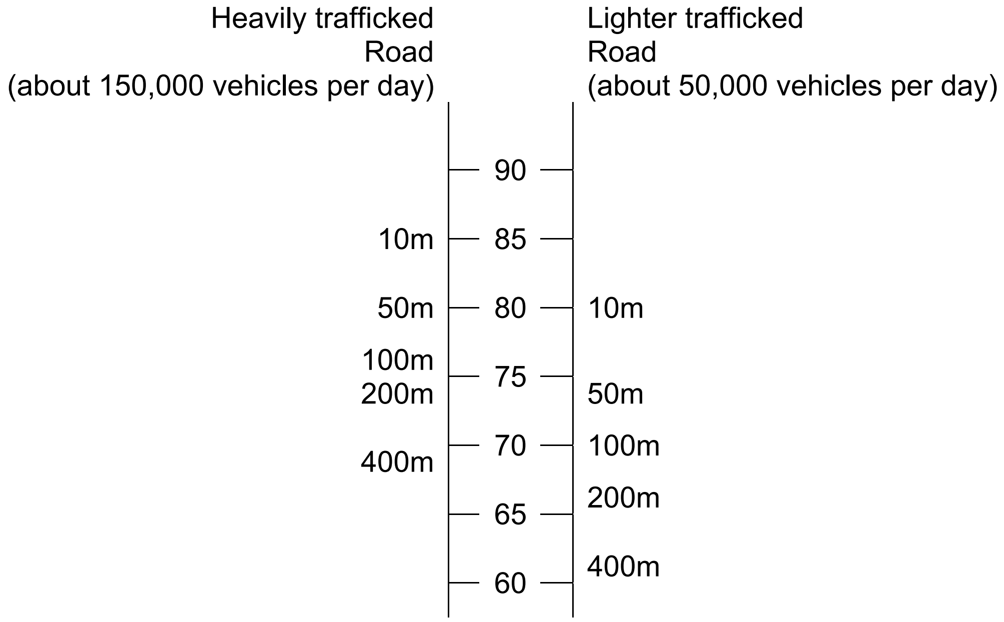

Figure A1.1: Example of Typical Traffic Noise Levels, $L_{A10,18h}$

A1.8 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.

A1.9 The frequency of sound is the rate at which a sound wave oscillates, measured in number of cycles per second, or Hertz (Hz). The human ear is more sensitive to frequencies important for voice communication and hearing sensitivity decreases markedly at frequencies below about 250 Hz. Frequencies below 20 Hz are usually perceived as vibration. The upper frequency limit of audibility is around 20 kHz, but decreases with age.

A1.10 Several different weightings have been proposed to convert measured sound pressure to a measure that correlates with perceived loudness in different circumstances. The ‘A’ weighting is by far the most commonly used and correlates well with the perceived noisiness of road vehicles. Logically the characteristics of the weighting should be slightly different for higher level sounds.

A1.11 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 demonstrated between this index and residents’ expressed dissatisfaction with traffic noise over a wide range of exposures. In addition, the prediction and measurement techniques using this index are well developed in the UK.

A1.12 A commonly used alternative index is the equivalent continuous sound level, L_{Aeq}, which is the level of a notional continuous constant noise that would deliver the same sound energy over the period of measurement as the actual intermittent or time varying noise. Using this measure, a fluctuating noise can be described in terms of a single noise level. This index is easily adapted to describing sources that consist of occasional short periods of noise interspersed with relatively long quiet periods – for example, intermittent noise from industry, construction or demolition activity, and from railways and aircraft. However, it does not appear to provide a better correlation with people’s dissatisfaction with road traffic noise than the L_{A10} index.

A1.13 An index sometimes used to describe background noise levels in the absence of a dominant source is L_{90}, 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 and there has been no research to assess how it correlates with people's reactions to noise, nor on how it can be modelled.

ANNEX 2 RESEARCH INTO TRAFFIC NOISE AND VIBRATION

A2.1 Many surveys have investigated the relationship between traffic noise and its impact on people. “Nuisance” and “Annoyance” are often used as general terms to describe this impact, and surveys usually employ ratings on scales such as satisfaction-dissatisfaction or “bother” as a way of measuring it.

A2.2 The early survey work compared noise and nuisance levels at sites where conditions were generally steady – i.e. no sudden changes in exposure had recently taken place or were in prospect. Such surveys yield “steady state” relationships between noise exposure and nuisance. Figure A3.1 shows a “steady-state” relationship between noise exposure and noise nuisance, derived from three surveys (Ref 17, 23 and 29).

A2.3 Nuisance here is measured as the percentage of people bothered by traffic noise (i.e. those who say they are “very much” or “quite a lot” bothered by noise on a four point scale, which includes “not much” and “not at all” as alternatives). Figure A3.2 shows a relationship between changes in noise nuisance (on the same nuisance scale) and changes in noise exposure.

A2.4 Later surveys of residents before and after changes in noise exposure had occurred as the result of road projects indicated that people are more sensitive to abrupt changes in traffic noise than would have been predicted from the steady state evidence described above. In the period following a change in traffic flow, people may report positive or negative benefits when the actual noise changes are as small as 1 dB(A). As this noise change is equivalent to an increase of 25% or a decrease in traffic flow of 20%, this reaction may be partly attributed to an awareness of the changes in traffic rather than noise.

A2.5 These enhanced reactions last for a number of years and may persist as long as the respondents are those who were interviewed before the change took place. In the longer term, the level of nuisance may tend towards the steady state level associated with the noise exposure as the population interviewed acquires new residents who have no memory of the prior situation.

A2.6 The level of nuisance generated by the opening of a project has been shown to persist for seven years at least. It seems clear that people living in a previously quiet area will continue to notice the excess noise caused by traffic, but people moving into the area will take account of it in making their choice of house. It is arguable that by the future assessment year changes in population may well cause overall nuisance levels to return to those predicted by the steady-state relationship.

A2.7 The methods of assessing nuisance in the steady state and as the result of changes in noise level are described in Annex 3.

Sleep Disturbance

A2.8 Measurements of noise from roads indicate that on average nighttime traffic noise (i.e. noise between 23:00 and 07:00 on the following day) is approximately 10 dB(A) less than daytime levels. The 18 hour average noise level only takes some account of the nighttime period.

A2.9 There is mounting concern about disturbance from heavy goods vehicle movements during the hours of night and early morning. Noise in the hours before 6am can cause people to awaken earlier than they would otherwise. Similarly, noise from heavy lorries late at night is likely to cause some people difficulty in getting to sleep. Much of the research on sleep disturbance has focussed on aircraft noise, but the noise of isolated heavy vehicles has strong similarities to the effect of aircraft during otherwise quiet periods.

A2.10 A comprehensive synthesis of field and laboratory studies undertaken before 1980 concluded that sleep disturbance could be significant at quite low noise levels (Ref 26). Attempts to find a relationship between sleep disturbances reported in social surveys and noise indices have indicated that there is a rather poor correlation between awakenings and measurements or predictions of noise.

A2.11 Research undertaken in America (Ref 10) on the impact of nighttime road traffic noise in cities has indicated that 25% of people exposed to an external noise level of 54 dB L_{Aeq} between the hours of 10pm and 6am were very annoyed; the percentage very annoyed rose to 50% for noise level of 65 dB L_{Aeq}. These rates of annoyance are comparable with the result of applying the annoyance relationship given in Figure A3.1 to a noise level 10 dB(A) higher than that measured at night. Although this time period (i.e. 10pm to 6am) is different to that used for the assessment of nighttime noise in this document, it is considered that a similar relationship for annoyance would exist.

A2.12 A more recent meta-analysis of sleep studies undertaken for the EU (Ref 22) has found relationships between the number of noisy events and proportion of people disturbed by aircraft, railways and road traffic at night. The approach recommended to the EU has converted this data into a method of predicting the proportion of people likely to be disturbed from the average nighttime noise exposure for different sources. However, as these relationships have been based on self-reported disturbance, it is not surprising that they diverge from the DfT study, which was based on measuring body movements. The EU relationship for nighttime disturbance from road traffic produces much lower rates of annoyance than found in the German study. There is a clear tendency for road traffic noise to be considered more disturbing than railway noise, which is consistent with the trend found for daytime noise.

Low Ambient Noise

A2.13 While there is an accumulation of evidence about the adverse impacts of noise from new roads through quiet country areas mainly in the form of complaints, objective research has been rather limited.

A2.14 A preliminary study by TRL of a rural bypass (A41 Kings Langley/Berkhamsted) concluded that although people living in quieter surroundings tended to be rather articulate and live in relatively expensive dwellings, there was not enough evidence to show that the impact of noise changes in this case was any different from that predicted from earlier bypass studies where ambient noise levels were higher.

A2.15 The distance over which traffic noise can be detected in rural areas, especially under favourable conditions, is extensive and may give rise to a large number of complaints. As noise is attenuated according to the logarithm of distance, differences in source noise are translated into relatively large changes in the area affected when the threshold of detection is low.

Noise Hotspots

A2.16 Previous studies of the impact of noise changes had been undertaken in cases where there had been significant changes in traffic. The provision of noise mitigation measures at a selection of noise "hotspots" on England's Strategic Road Network where there had been a history of complaints about high levels of noise gave an opportunity to study reactions to noise changes where the traffic generally remained unchanged.

A2.17 The measures were either noise barriers, or quieter surfaces, or in one case a combination of the two. Surveys similar to those conducted in the bypass studies were undertaken before and after implementation of the measures. Although there were one or two anomalies, the trend of responses was to confirm a reduction in the level of dissatisfaction that broadly corresponded with the change in noise level in accordance with the steady state relationship.

A2.18 However, there was strong evidence of a higher level of dissatisfaction with the noise level before the change than would have been expected from the "steady state" relationship. This was attributed to a degree of sensitisation as the result of local campaigning and possibly enhanced by anticipation of the change. In at least one case, an increase in dissatisfaction was attributed to disappointment with the reduction in noise actually achieved by the measures compared with expectations.

Effects on Fauna

A2.19 Noise from man-made sources can affect animal behaviour where it masks sounds that are important to their ecology. Examples of impacts are on the breeding behaviour of birds and on prey-predator interactions e.g. owls and small mammals. Most research has been directed at effects of noise on birds.

A2.20 Research in the Netherlands has indicated a wide range of sensitivity, both according to species and depending on whether the noise is continuous or intermittent. It is well-known that colonies of geese for example thrive near airfields where the advantages of relative seclusion overcome the disturbance due to noise. Ducks, on the other hand, appear to be more sensitive to aircraft noise. Dutch research (Ref 25) on the effects of traffic noise showed an increasing impact with increasing noise levels above about 45 dB L_{Aeq} for a range of woodland, marsh and grassland species in certain circumstances. The threshold of sensitivity to traffic noise of coot was 60 dB, similar to that shown by black duck to aircraft noise. If considering any impact of noise on birds, care must be exercised in relation to the height of the receptor for which the noise predictions are conducted. The noise levels experienced by birds also depends upon on the habitat and behaviour of the birds because they experience different rates of attenuation in different environments.

Nuisance Where Traffic is not Freely Flowing

A2.21 Langdon (Ref 18) found that at sites where traffic does not flow freely, perceived noise nuisance was only weakly related to existing noise indices. The best predictor of noise nuisance at non free-flow sites was found to be the logarithm of the percentage of heavy vehicles (greater than 1525 kg gross weight) in the traffic flow. However, since Langdon carried out these surveys in the early 1970s, noise emissions from heavy vehicles have been reduced to conform with successive amendments to the vehicle type approval limits.

A2.22 There would be inconsistencies if different methods of predicting nuisance were used in locations where traffic is not free flowing for part of the day. It is therefore recommended that Figure A3.1 in Annex 3 is used to estimate noise nuisance even on routes where traffic is not free flowing, taking account of the effect of reduced speeds on noise during periods of congestion if hourly speed/flow data is available.

A2.23 Speed variations at junctions should generally be ignored in assessing noise nuisance as there is a trade-off between the effects of reducing speed and the additional engine noise generated by deceleration and acceleration. An appropriate average speed may be used for predicting the noise from traffic on large gyratory systems.

Vibration Effects

A2.24 There are two impacts of traffic vibration that need to be considered; impacts on buildings and disturbance to occupiers.

i) Impacts on Buildings

A2.25 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 (Ref 28), 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 (i.e. existing heavily trafficked roads with poor surfaces and sub grade 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.

A2.26 Significant ground-borne vibrations may be generated by irregularities in the road surface. Such vibrations are unlikely to be important when considering disturbance from new roads and an assessment will only be necessary in exceptional circumstances. Furthermore, as the irregularities causing ground-borne vibration can be rectified during maintenance work, relief of these vibrations should not be presented as a benefit of a new project.

ii) Disturbance to Occupiers

A2.27 Ground-borne vibration is much less likely to be the cause of disturbance than airborne vibration, but where it does occur the impacts can be more severe. At highest risk are occupants of buildings founded on soft soils close to heavily trafficked older roads where the road surface is uneven or constructed from concrete slabs which can rock 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 (Ref 28).

A2.28 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 (Ref 4 and 29). It was found that $L_{A10,18h}$ index was among the physical variables most closely associated with average vibration disturbance ratings.

ANNEX 3 ASSESSING TRAFFIC NOISE AND VIBRATION NUISANCE

A3.1 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.

A3.2 Attempts to measure noise nuisance or annoyance usually make use of questionnaire surveys that attempt to relate the degree of annoyance expressed by the people interviewed with some physical measurement of the source noise level. 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.

A3.3 Given this variability in individual responses, practical research has moved from the ideal of explaining individual attitudes or annoyance with noise and has instead adopted the concept of an average or community annoyance rating for each noise level.

A3.4 Most of the information on the relationship between traffic noise and perceived traffic noise nuisance comes from studies in which the noise exposure has been fairly stable, with changes (mostly increases due to traffic growth) taking place over many years. There have been many such studies, and while the rate of change in nuisance with change is noise has been fairly consistent across all surveys, the absolute level of nuisance at any given noise level tends to vary from survey to survey. Figure A3.1 shows a curve derived from the combined data of a number of these steady-state surveys (Ref 17, 23 and 29).

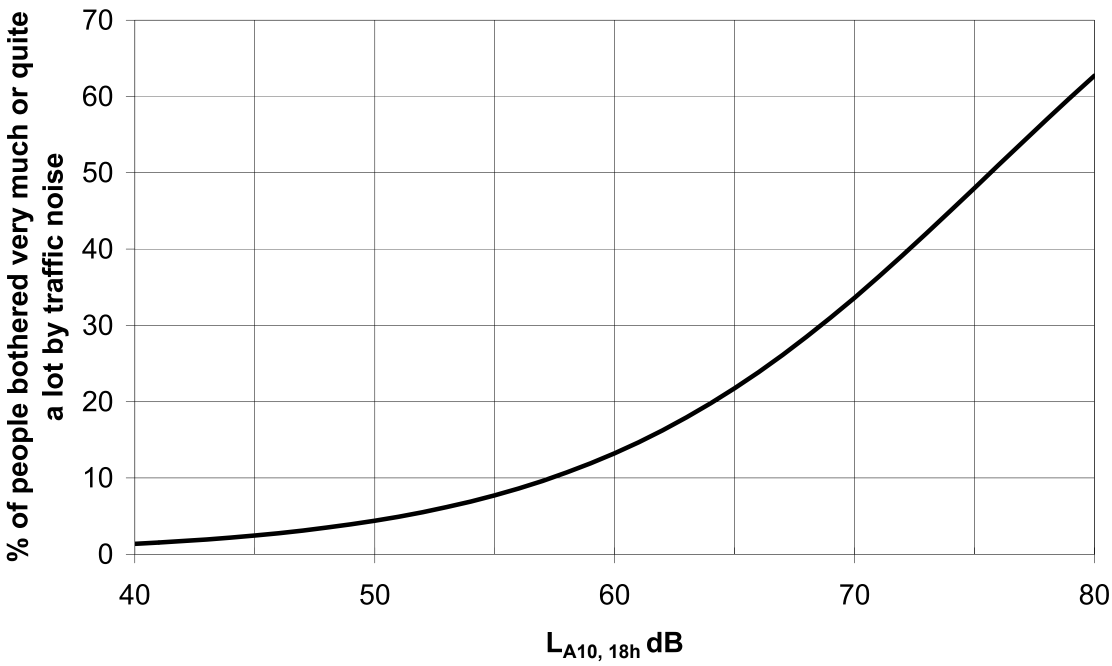

Figure A3.1: Estimation of Traffic Noise Nuisance – Steady State or Before Noise Change

A3.5 The curve in Figure A3.1 was derived from the results of these three surveys. For each survey the mean % bothered was calculated for each 2 dB(A) band. The curve was the best fit through the resultant set of points. The curve has been derived from the equation:

$$\% \text{ bothered} = \frac{100}{1+e^{-\mu}} \quad \text{, where } \mu = 0.12$$

$(L_{A10,18h}\ \text{dB}) - 9.08$

A3.6 A number of studies have measured changes in perceived noise nuisance associated with changes in traffic exposure (Ref 5, 11, 16 and 19). These studies have found that nuisance ratings change more than would be predicted from the "steady-state" relationship shown in Figure A3.1. The possible explanations for this excess change in nuisance are complex, and are discussed by Huddart and Baughan (Ref 16). However, the excess annoyance appears to reflect a real change in nuisance that persists for several years.

A3.7 The change in nuisance ratings in these situations can be estimated from Figure A3.2. This curve was based on "before" and "after" studies at 14 sites in England (Ref 16), supplemented by data from seven site studies by Griffiths and Raw (Ref 11). 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 TRL steady-state surveys. However, an adjustment was applied to the "decrease" part of the curve, as described below.

A3.8 Huddart and Baughan (Ref 16) 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 given.

A3.9 The first is that 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 that the project being appraised came forward in the same way as the projects covered by the research surveys.

A3.10 Second, 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.

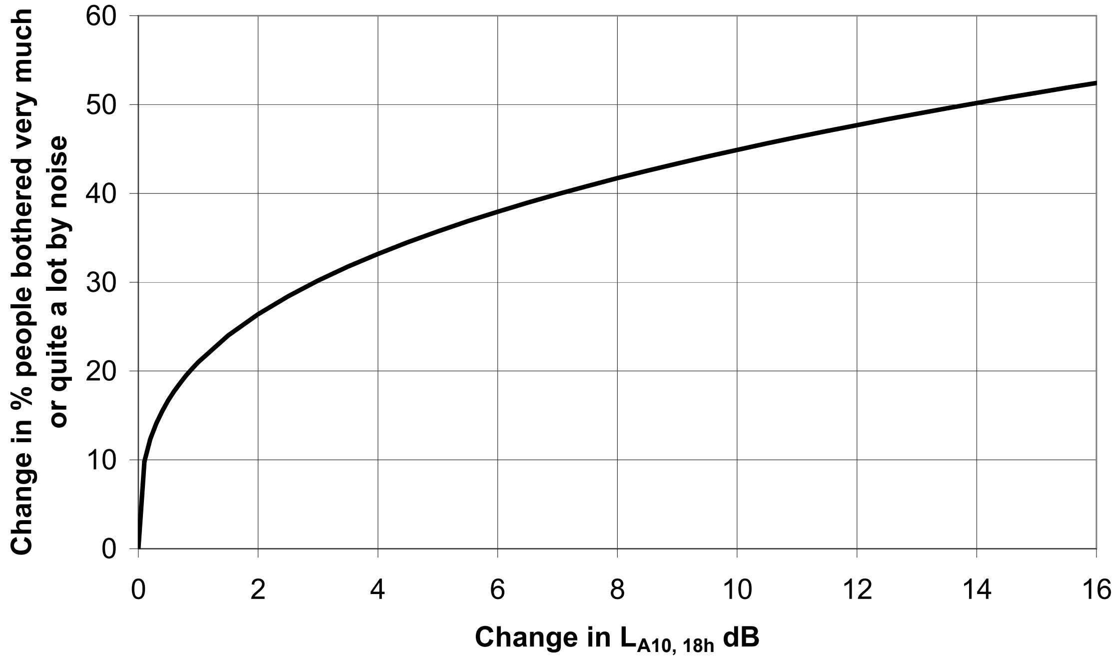

Figure A3.2: Estimation of Traffic Noise Nuisance – Change in % Bothered Very Much or Quite a Lot by Traffic Noise

A3.11 This curve has been derived from the equation:

Change of % bothered = 21 (Change of $L_{A10,18h}$ dB)0.33

A3.12 Huddart and Baughan argue that both the above impacts 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 relationship between the two scales derived from 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.

A3.13 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.

A3.14 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.

A3.15 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 A3.2, therefore, shows a single curve applying to both increases and decreases.

A3.16 Research indicates that the large nuisance changes observed in before and after studies are not simply short term impacts. Griffiths and Raw (Ref 12) 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.

A3.17 The assessment method described in this advice assumes that this does happen, and that the nuisance 15 years after a project 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.

A3.18 The method for assessing traffic noise nuisance described in this manual will give estimates for an "average" site. The level of annoyance caused by changes at any individual site may differ from this "average" estimate.

A3.19 It should be made clear that the surveys which provided the basis for this method of assessing nuisance were conducted at sites where road traffic was the dominant noise source. Noise exposures 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.

A3.20 When the pre-project noise level is not dominated by traffic noise, it should be measured using the noise index $L_{Aeq,18h}$. It is recommended that this is used as a substitute for $L_{A10,18h}$ to estimate pre-project levels of nuisance in these situations, using Figure A3.1. When estimating the change in nuisance from Figure A3.2, the difference between the "after" level of noise as $L_{A10,18h}$ and the "before" noise level as $L_{Aeq,18h}$ should be used.

A3.21 The method is based on surveys of noise changes caused by changes in traffic volume. 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. A recent study has shown that although a noise reduction by such means reduced nuisance, the limited number of responses showed this decrease not to be as great as where actual traffic volume changes occur. However, further research is required before traffic noise nuisance changes can be estimated for these situations with any certainty.

A3.22 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 A3.1 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 L_{A10} dB and, therefore, zero per cent should be assumed in these cases.

A3.23 The survey of vibration nuisance was restricted to dwellings within 40 metres of the carriageway where there were no barriers to traffic noise. When using this graph to make predictions of disturbance caused by airborne vibration, professional judgement is needed in cases where the buildings are screened or are not sited within 40 metres of the road, since this is outside the range of the data on which the empirical method is based.

Table of data from Figures A3.1 and A3.2

Figure A3.1

Noise exposure, $L_{A10,18h}$ dB	Approx % bothered by traffic noise
<41	1
41-45	2
45-48	3
48-50	4
50-52	5
52-54	6
54-55	7
55-56	8
56-57	9
57-58	10
58-59	11
59-60	12
60-61	14
61-62	15
62-63	17
63-64	19
64-65	21
65-66	23
66-67	25
67-68	27
68-69	29
69-70	32
70-71	35
71-72	38
72-73	40
73-74	43
74-75	46
75-76	49
76-77	52
77-78	55
78-79	58
79-80	61
80-81	64
82-83	68
83-84	72
84-85	75
>85	79

Figure A3.2

Change in noise exposure, dB	Change in % bothered by traffic noise
<2	23
2-3	28
3-4	31
4-5	34
5-6	37
6-7	39
7-8	41
8-9	42
9-10	44
10-11	45
11-12	47
12-13	48
13-14	49
14-15	51
>15	53

Noise Nuisance Changes: Worked Examples

Example 1. Do-Minimum

(i) Do-Minimum in the baseline year noise level of 68.2 dB $L_{A10,18h}$ 29 per cent of people are bothered by traffic noise (Figure A3.1).

(ii) In the future assessment 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 A3.1).

(iii) There will therefore be an increase of five percentage points, in the number of people bothered, and this value should be entered into the assessment table.

Example 2. Increases in traffic noise

(i) Do-Minimum in baseline year noise level of 65.9 dB $L_{A10,18h}$ 24 per cent of people are bothered by traffic noise (Figure A3.1).

(ii) An increase of 3.0 dB $L_{A10,18h}$ is predicted in the baseline year as a result of the project, so the immediate increase in the percentage of people bothered will be 30 percentage points (Figure A3.2), so 54 per cent will be bothered.

(iii) By the future assessment 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 A3.1).

(iv) The highest level of bother (54 per cent) is therefore on opening, and the increase in bother for the assessment table is, therefore, 30 per cent.

Example 3. Decreases in traffic noise

(i) Do-Minimum in baseline year noise level of 73.1 dB $L_{A10,18h}$ 42 per cent of people will be bothered (Figure A3.1).

(ii) A noise reduction of 6.0 dB $L_{A10,18h}$ to 67.1 dB $L_{A10,18h}$ is expected in the baseline year as a result of the project, so the immediate decrease in the percentage of people bothered will be 38 (Figure A3.2), so 4 per cent will be bothered.

(iii) By the future assessment 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 A3.1).

(iv) The highest level of bother is therefore in the future assessment year, and the reduction in bother is 13 per cent, and this value should be entered into the assessment table.

ANNEX 4 ADDITIONAL ADVICE TO CRTN PROCEDURES

A4.1 Since the revision of the technical memorandum Calculation of Road Traffic Noise (CRTN) in 1988 (Ref 9), there have been significant advances in road design, the development of new surface materials and improvements in noise mitigation. In addition, over the intervening years certain procedures have required further clarification. It is therefore timely to address some of these issues and provide additional advice for assessment to that already published in CRTN.

A4.2 It is acknowledged that there are other areas where the methodology contained within CRTN may not fully take into account the influences of certain features or conditions. However, these areas have not been addressed in the following text as there is currently insufficient knowledge or research to support any changes.

A4.3 Where calculations are being undertaken for entitlement purposes under the relevant Noise Insulation Regulations, the use of this advice should be considered and discussed with the Overseeing Organisation.

Dual Source Lines

A4.4 In 1989 the Secretary of State for Transport announced additional measures to relieve congestion on major roads in England which included increasing the capacity of existing routes by introducing road widening projects, typically 4-lane dual carriageways.

A4.5 A fundamental assumption in the CRTN method is that the noise from a stream of traffic distributed over the entire width of the highway can be simulated by a single source line positioned 3.5 metres in from the nearside carriageway and 0.5 metres above the road surface. A consequence of these new road widening projects was to increase the spread of traffic across each carriageway than had previously been examined when the method was first developed.

A4.6 Research carried out by TRL in 1994 recommended that the procedures which already exist in CRTN for predicting the noise from separate carriageways (paragraph 13.1) should also apply to dual carriageway roads with four or more lanes per carriageway, irrespective of the horizontal separation or vertical alignment of the carriageways (Ref 1).

A4.7 However, in adopting a dual source line approach for dual carriageways with 4 or more lanes does introduce an inconsistency when up-grading an existing 3-lane dual carriageway to four lanes. The pre-project noise levels would be based on a single source line model compared with post-project predictions assuming a dual source line approach.

A4.8 A further problem can arise where a barrier alongside a dual carriageway only provides partial screening. Prediction of noise levels at a receiver which is sufficiently elevated that traffic on the farside carriageway is not screened by the barrier may be significantly underestimated where a single source line model is adopted compared with a dual source line approach (Ref 27).

A4.9 Furthermore, under certain circumstances, particularly where a receiver is close to a dual carriageway i.e. less than about 50 metres and the traffic is not screened, noise levels predicted using the dual source line model will give lower values than corresponding levels calculated using a single source line approach. However, when predicted noise levels are compared with measurements there is evidence to suggest that the dual source line model performs marginally better than the single source approach under such site conditions (Ref 24).

A4.10 To resolve these problems and provide a method which is internally consistent, it is recommended that the dual source line approach is adopted for all dual carriageways.

Median Barriers

A4.11 Median barriers, designed to prevent vehicles from crossing the central reserve, may provide additional benefits in screening noise. Where a concrete barrier is constructed along the central reserve, the screening performance of the barrier relating to the farside source line should be taken into account according to the procedures described in paragraph 22 of CRTN.

A4.12 In situations where there is additional screening, for example from a purpose-built noise barrier erected alongside the nearside carriageway, then the combined screening of both barriers should be calculated according to the procedures described in paragraph 35 of CRTN when calculating the noise contribution from traffic on the farside carriageway. Generally, the height of the median concrete barrier above the road surface is less than 1.5 metres and therefore reflection effects from the nearside source line are negligible. However, where the height of the median concrete barrier is equal to or greater than 1.5 metres, a reflection correction is required when calculating the noise contribution from the nearside traffic and calculated according to the procedure described in paragraph 26.2 of CRTN or paragraph 36 where there is additional screening provided by a barrier alongside the road.

Vehicle Classification

A4.13 The vehicle classification system described in CRTN identifies two vehicle groups ‘light vehicles’ and ‘heavy vehicles’ which are defined according to the unladen weight of the vehicle i.e. vehicles with unladen weight greater than 1.525 tonnes are classified as ‘heavy vehicles’. The classification assumes that vehicles within each group are acoustically similar. However, since this classification system was first introduced in 1975, the proportion of vehicles within the range 1.525 tonnes to 3.5 tonnes has grown significantly and the maximum permissible weight of heavy vehicles has increased from 38 to 44 tonnes. Therefore, the range in vehicle noise emissions within the heavy vehicle category has increased. To address this problem it is recommended that the heavy vehicle category is redefined as vehicles with unladen weight greater than 3.5 tonnes.

Traffic Forecasts and Speeds

A4.14 Noise calculations need to be carried out for both the Do-Minimum and Do-Something conditions in the baseline year and for the worst case within fifteen years of the project opening. The traffic flow used in the calculations shall be that expected between 06.00 hours and midnight on an average weekday in the appropriate year. The most likely growth forecast should be assumed in the calculations for determining predicted noise levels in future years. However, where particular local conditions indicate growth forecasts significantly different from these or where unusual traffic patterns exist then the local data are to be applied.

A4.15 Traffic noise is sensitive to changes in speed and CRTN includes a table of traffic speed values typical for different road types that are to be used as default values when no other data is available. However, the speeds based on the TUBA off-peak flow group should be used whenever possible, providing the traffic consultant is confident that the TUBA speeds are appropriate for the link (Ref 13). Alternatively, in some situations, it may be possible to use observed speeds if the measurements are robust. However, it should be recognised that the correction for speed within the CRTN method is only valid within the range 20 to 130 km/hr. Where the mean traffic speed falls outside this range then the input speed used in CRTN should be the appropriate speed limit as defined above.

Surface Correction for Thin Surfacing Systems

A4.16 CRTN provides advice on appropriate road surface corrections to be applied within noise assessments and this advice should continue to be used. However, this advice does not currently extend to the range of proprietary thin bituminous surfacing materials and commonly regarded as a low-noise surfacing which emerged in the late 1990’s.

A4.17 Low-noise surfaces are normally characterised by their ‘Road Surface Influence’ (RSI) value, which provides a measure by which they can be specified in highway works under the Highways type approval scheme HAPAS (Ref 6). However, the RSI value alone does not give an indication of the long-term performance of the surface. In addition, no long-term measurement data is currently available for thin surfacing systems from which any robust correction factors for use in noise assessments can be readily obtained.

A4.18 In the absence of more accurate long-term data, it is generally considered that thin surfacing systems will not be able to provide better long-term noise reduction performance than other low-noise surfaces such as porous asphalt.

A4.19 On the basis of results from RSIH (High speed) measurements on a porous asphalt surface and the accepted correction of –3.5 dB(A) implicit in the CRTN method, the following interim relationship has been developed to estimate the benefit of thin surfacing systems for use in noise assessments:

$$\text{Surface correction for thin surfacing systems} = 0.7 * (\text{RSI}) \text{ dB} \quad \text{(A4.1)}$$

where RSI ≥ -5 dB(A) and derived from the HAPAS approval scheme for high or medium speed roads, RSIH or RSIM , respectively. For an RSI < -5 dB(A) an RSI of -5 dB(A) should be entered into equation A4.1.

A4.20 Therefore, as a result of applying the equation A4.1, **for any situation a maximum allowable surface**

correction of -3.5 dB(A) can be claimed from using thin surfacing systems, compared with hot rolled asphalt surfaces.

Existing Low-noise Surfaces

A4.21 Where the benefit of an existing thin surfacing system needs to be determined, information regarding RSIH or RSIM for the existing surface should be sought from the Overseeing Organisation in order to obtain an appropriate surfacing correction using equation A4.1.

A4.22 Where an RSI value has been determined through measurements then this value should be entered into equation A4.1 to derive a surface correction, taking into account the limitations given in A4.16. This RSI value could have been derived from measurements on the surface in question or on a surface of the same specification from the same manufacturer elsewhere.

A4.23 If there is no information available, a -2.5 dB(A) surface correction should be used.

A4.24 Alternatively, recourse to the measurement method described in CRTN-Section III can be used to estimate the basic noise level which would include the influence of the road surface on traffic noise levels and the façade noise levels determined according to the procedures described in paragraph 37. However, applying this method may not provide a reliable estimate of RSI when comparing measured and predicted noise levels due to other contributing factors. For example, the RSI value will be dependent on the proportion of heavy vehicles in the traffic stream and it is therefore advisable that measurements are carried out when traffic conditions are typical for the 18-hour period (06:00 to midnight). However, where the RSI value is required as input to equation A4.1 to determine the surface correction to be used in CRTN, recourse to the measurement method as described in the HAPAS approval scheme should be applied.

New Low-noise Surfaces

A4.25 Where new carriageways are to be constructed and a thin surfacing system used, or where an existing surface is to be replaced with a thin surfacing system, a -3.5 dB(A) correction should be assumed for the thin surface system (i.e. equivalent to a -5 dB(A) value being entered into equation A4.1), unless any information is available regarding the specific surface to be installed.

Assumptions and Limitations

A4.26 Generally the RSIH or RSIM is determined by averaging the results from at least two sites. If the information for each site is known, then, for the purposes of determining the surface correction for thin surfacing systems the least negative value should be used for RSI and the surface correction determined from equation A4.1.

A4.27 For both existing and new road projects, these corrections only apply to where all carriageway lanes are surfaced with a thin surfacing system. No correction should be applied where only discrete sections have been surfaced, such as individual carriageway lanes, whether existing or planned.

A4.28 For roads not subject to a speed limit of less than 60 mph and the mean traffic speed is ≥ 75 km/hr, the RSIH value should be used to determine the RSI value and the surface correction determined using equation A4.1.

A4.29 Similarly, for roads subject to a speed limit of 50 mph and the mean traffic speed is ≥ 75 km/hr, the RSIM value should be used to determine the RSI value and the surface correction determined using equation A4.1.

A4.30 The above advice applies to roads where the mean traffic speed is ≥ 75 km/hr. Although it is likely that thin surfacing systems will provide acoustic benefits at lower speeds, until further research is carried out to provide reliable estimates, it advised that a qualitative statement highlighting the possible acoustic benefits should be included in the assessment.

Extrapolation Beyond 300 Metre Limit

A4.31 Research carried out by TRL has shown that noise levels from field measurements out to 600 metres from a motorway, where the intervening ground cover was grass, were in good agreement with predicted noise levels using CRTN with the attenuation with distance functions, Chart 7 and 8, extrapolated to 600 metres (Ref 2). It is therefore recommended that this is adopted for predicting noise levels out to 600 metres from the road. For distances greater than 600 metres from the road, predicted noise levels become less reliable and the benefits from ground absorption diminish with distance. An approximate indication of noise levels can be calculated by applying the attenuation with distance function Chart 7 (extrapolated to distances in excess of 600 metres) with the attenuation with distance function Chart 8 (extrapolated to 600 metres). For this it is assumed that the attenuation rate for distances in excess of 600 metres is approximately 3dB/doubling of distance.

Sound Absorptive Noise Barriers and Retained Walls

A4.32 Although CRTN recognises that sound absorptive noise barriers will reduce reflection effects when positioned along the opposite side of the road or where a road is flanked on both sides with sound absorptive noise barriers (paragraph 36iii), no allowance is given in the method to take this into account. Similarly, where a retaining wall has been designed with sound absorbing properties, no allowance is given in the method to take into account a reduction in reflection effects. However, to inform the decision process when assessing mitigation using noise barriers or retaining walls, an estimate of the additional potential benefits in noise mitigation provided by the use of sound absorptive materials in the design of noise barriers or retaining walls should be included in the assessment.

A4.33 The potential benefits should be calculated from the reflection correction as described in paragraph 26.2 or 36 depending on the type of road project. However, research carried out by TRL (Ref 31) has shown that the predicted benefits from changing a reflective barrier to one which is sound absorptive was over estimated by CRTN when compared with measurements. It is therefore recommended that where potential benefits of designing barriers or retaining walls with sound absorbing materials are included in the assessment it is stressed that these benefits are likely to be overestimated and should only be used as a guide to their performance.

Reflection from Opposite Facades

A4.34 Reflection from opposite facades, paragraph 26.2 of CRTN, provides a correction for reflections where there are houses, other substantial buildings or a noise fence or wall beyond the traffic stream along the opposite side of the road. However, there is no advice given concerning the position of the reflecting façade relative to the position of the traffic stream to determine when to apply the correction. Research based on a theoretical model has shown the reflection correction is dependent on the ratio of the distance between the receiver and the source line and the distance between the source line and the opposite façade (Ref 14). From this work the following advice is recommended when determining whether the reflection from opposite facades (including barriers) should be applied.

Apply correction for reflection effects from opposite facades:

1. when $d < 12$ m and $D \leq 20$ m

or

2. when $12 \text{ m} < d \leq 300$ m and $D \leq 10^{(0.825\ +\ 0.4\log_{D}(d+3.5))}$ m

where

d is the horizontal distance between the receiver and the nearside kerb and D is the horizontal distance between the source line and the opposite façade.

Congestion Management Schemes

A4.35 The assessment of projects that are designed to manage and reduce congestion are not specifically covered in the CRTN procedures. Advice is given below on methods to adopt when calculating traffic noise from various regimes. Advice from the Overseeing Organisation should be sought where congestion management regimes are not covered by the advice given below. If any calculations are being undertaken to assess entitlement under the relevant Noise Insulation Regulations then an approach should be discussed with the Overseeing Organisation.

A4.36 **Variable speeds.** The modelling of roads with a variable speed limit should be undertaken as normal with any predicted changes in average traffic speed together with changes in flow and composition being taken into account by the input parameters to the noise calculations.

A4.37 **High occupancy lanes.** If the project does not provide additional lanes then the assessment of such a regime should be treated as a normal, with the effect of the high occupancy lane being taken into account by any predicted changes in traffic parameters. Where additional lanes are included, the position of the source line may need to be adjusted where this effects the position of the edge of the carriageway. Modelling on a lane by lane basis is not recommended without agreement from the Overseeing Organisation.

A4.38 **Ramp metering.** Using CRTN to calculate traffic noise levels from a ramp metering project is not recommended. The impact of such a regime is likely to be very localised and therefore may be better described by a Qualitative entry. If it is considered by the Designer that a Quantitative assessment is required then the scope of this should be agreed with the Overseeing Organisation. Where ramp metering is part of a larger project then this advice should still be used.

A4.39 **Hard Shoulder Running.** If an assessment is being undertaken of a project involving Hard Shoulder Running then it is recommended that in the Do-Something condition the hard shoulder (or extra lane) is treated as the nearside lane for all periods in the 18 hour assessment.

Noise Measurements

A4.40 Noise measurements should not be undertaken within the 24 hour period after rainfall where a thin surface system is present on any section of road contributing to the noise climate. This applies to roads either partially or fully surfaced with a thin surface system, on either carriageway.

Shortened Measurement Procedure

A4.41 Although the following paragraphs do not provide any new advice, they contain analysis showing that the shortened measurement procedure is still a valid method for evaluating the $L_{A10,18h}$.

A4.42 The preferred method for calculating noise levels from road traffic is by prediction rather than by measurement (CRTN, paragraph 3). There are several reasons why the prediction method is preferred. In particular noise levels, although generally dominated by traffic noise, can be affected by non-traffic sources. Unless the extraneous noise from other sources is edited the results may lead to an over-estimation of traffic noise levels. However there are occasions when it is necessary to resort to measurements (CRTN, paragraph 38).

A4.43 The shortened measurement procedure deals with estimating the noise index $L_{A10,18h}$ by averaging three consecutively measured $L_{A10,1h}$ values carried out between 10:00 and 17:00 hours and subtracting 1 dB from the result. Since the method was first introduced in 1975 the pattern of traffic flow over the 18-hour period (06:00 to midnight) may have significantly altered due to changes in social behaviour (e.g. as society moves towards a 24-hour economy) and therefore it is important to establish whether the relationship used to estimate the noise index $L_{A10,18h}$ is still valid.

A4.44 To provide an indication of the accuracy of the method, values of the noise index $L_{A10,18h}$ measured outside residential dwellings at 1160 sites from the National Noise Survey carried out by the Building Research Establishment in 2000 were analysed (Ref 33). The survey was designed to represent the noise exposure outside residential dwellings in the UK. Although the measured noise exposure includes noise from all sources, the predominant noise source was from road traffic. The results of this analysis are described below.

A4.45 Figure A4.1 shows the relationship between the measured noise index, $L_{A10,18h}$ and the corresponding estimated values using the equation given in CRTN paragraph 43, as described above.

A4.46 The Figure shows that for all the five possible estimates of the noise index, $L_{A10,18h}$, there is a good correlation between the measured and estimated noise indices. The regression equation shows the best-fit line drawn through the data points which passes through the origin of the graph, indicating that 93% of the variance in the measured value can be accounted for by the regression equation ($R^2 = 0.93$). The slope of the regression equation (0.991) indicates that the relationship between the measured and estimated traffic noise indices that was developed over thirty years ago is still valid for today's traffic conditions.

A4.47 However, it should be noted that for measured values below 60 dB $L_{A10,18h}$ there is a noticeable increase in the scatter of the data compared with measured values above 60 dB $L_{A10,18h}$. A possible cause is that at quieter sites the dominant noise source may not be from road traffic alone or that traffic flows at quieter sites are likely to be low and the traffic pattern throughout the 18-hour period may be more variable than compared with the noisier sites where traffic flows are likely to be higher.

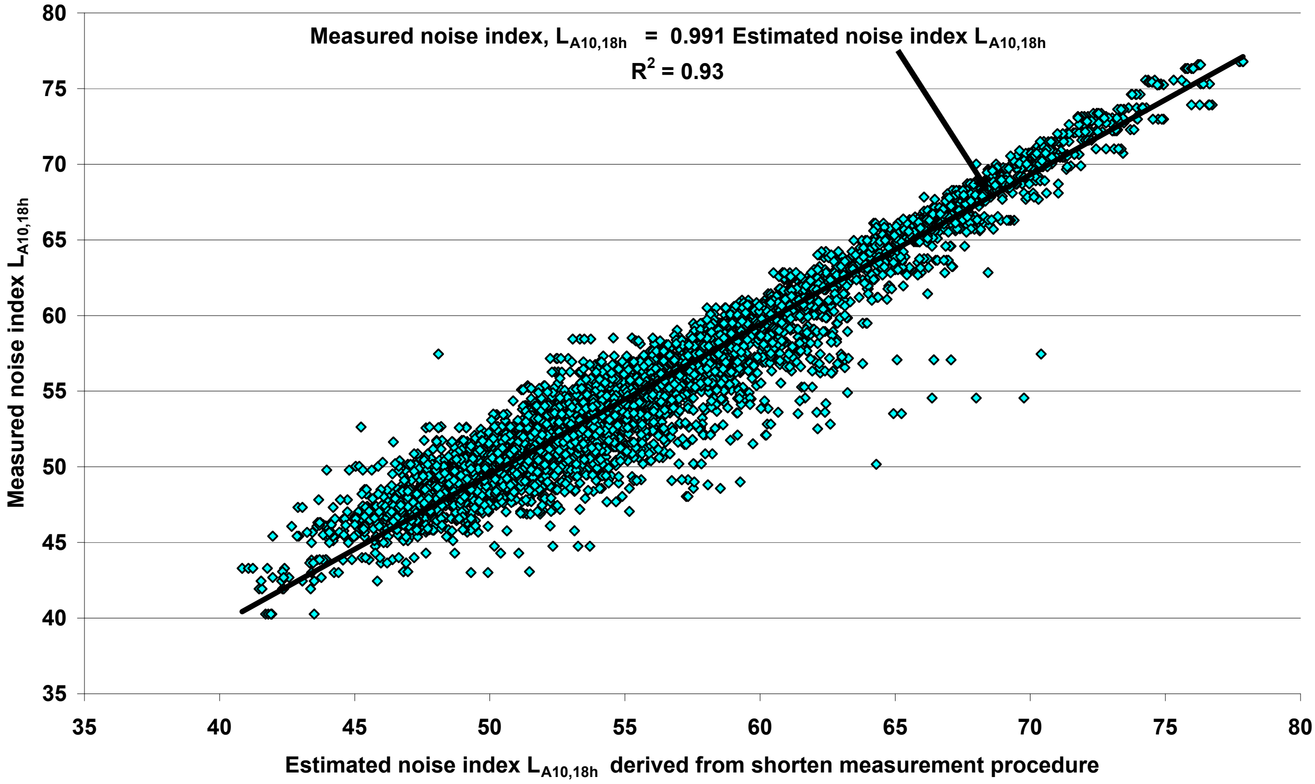

Figure A4.1: Relationship Between Measured and Estimated Noise Index $L_{A10,18h}$: BRE National Noise Survey 2000

A4.48 Figure A4.2 shows the same relationship as that shown in Figure A4.1 except that only those sites where the measured noise index was equal to or greater than 60 dB $L_{A10,18h}$ have been selected. As expected, the overall statistical relationship has improved with a significant reduction in the scatter of the data points around the regression equation.

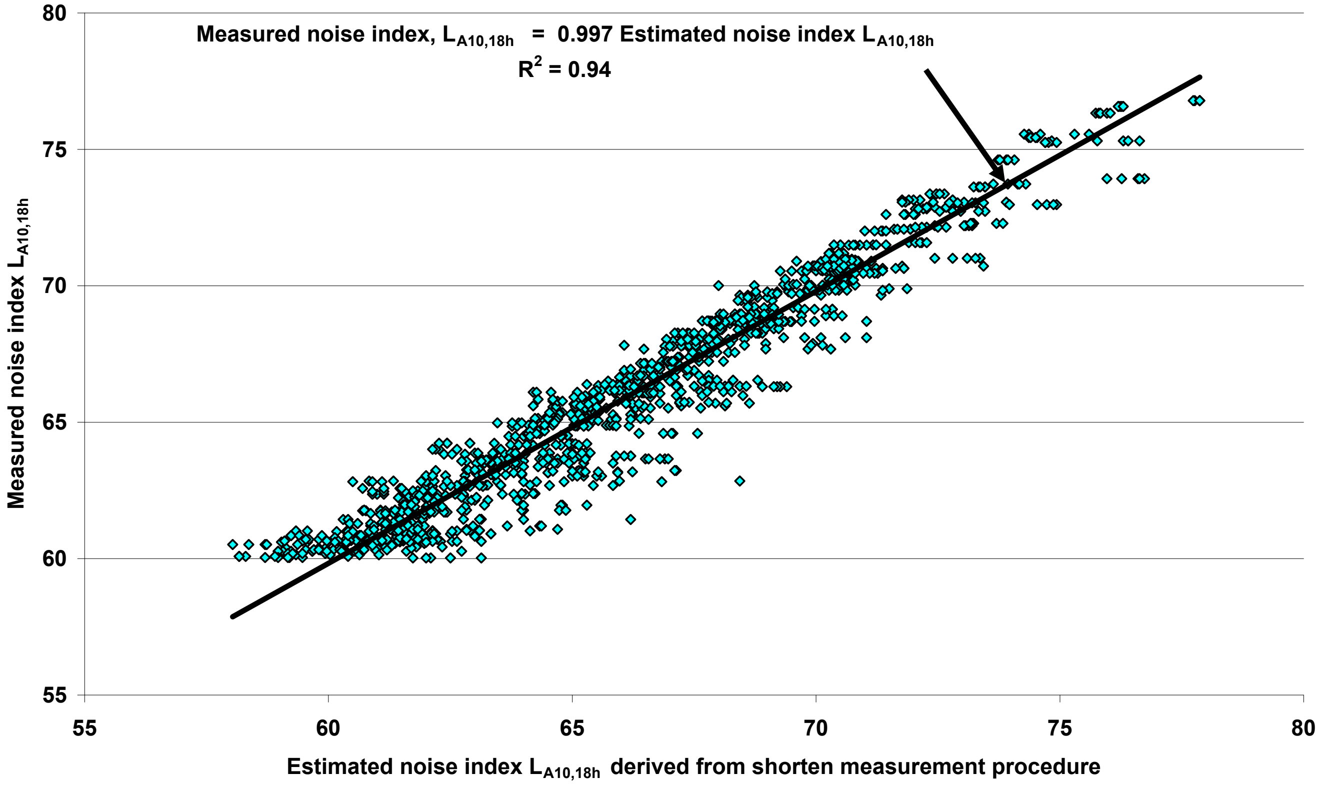

Figure A4.2: Relationship Between Measured and Estimated Noise Index $L_{A10,18h}$: BRE National Noise Survey 2000 – Measured Noise Levels > 60 $L_{A10,18h}$

A4.49 To illustrate this further, Table A4.1 shows the mean error (measured minus estimated $L_{A10,18h}$ values) and the standard deviation between the measured and estimated noise indices.

Sample	Number of data points	Mean error (measured-estimated) dB(A)	Standard error dB(A)
All	5800	-0.5	1.9
$L_{A10,18h} \geq 60$	1290 (30)	-0.2 (-0.4)	1.0 (0.8)
$L_{A10,18h} < 60$	4510	-0.6	2.0

[1] Values in brackets show corresponding results from similar surveys carried out in the early 1970's.

Table A4.1: Differences in Measured and Estimated Noise Index, $L_{A10,18h}$ Derived from BRE National Noise Survey 2000[1]

A4.50 For the whole data set, the mean error is -0.5 dB(A) indicating that on average the method slightly overestimates measured noise levels by 0.5 dB(A). The standard error provides an estimate of the range in the population mean e.g. a standard error of 1.9 dB(A) indicates that the probability of the measured value is within 2 standard errors (± 3.8 dB(A)) of the estimated value is 0.95.

A4.51 Restricting the sample to include only data where the measured index is equal to or greater than 60 dB $L_{A10,18h}$ not only improves the mean error to -0.2 dB(A) but significantly reduces the standard error to 1 dB(A). Comparing this result with the corresponding values derived from a similar but smaller survey carried out in early 1970's shows no significant difference and provides further evidence that the relationship has not significantly altered over the past 30 years. For completeness the corresponding statistics for sites where the measured index is less than 60 $L_{A10,18h}$ is also shown, indicating a mean error of -0.6 dB(A) and a standard error of 2 dB(A).

Sampling Period

A4.52 There is allowance in the measurement procedure as described in CRTN for hourly noise levels to be estimated by sampling over shorter periods. The minimum length of sample required to obtain a valid estimate of the hourly noise level is dependent on a number of factors as given in paragraph 41.2 of CRTN. An additional consideration in determining the period of sampling is when the traffic flow is not freely flowing, particularly when measuring near to junctions or roundabouts. It is advised that under such traffic conditions, sampling over the whole hour should be adopted when determining hourly noise levels.

Wind Conditions

A4.53 In paragraph 4, CRTN contains the statement '…noise propagation conditions are consistent with moderately adverse wind velocities…'. This statement is often misinterpreted and an explanation of the background is given below. During the development of the algorithms used for CRTN, measurements were undertaken to develop the relationship between traffic flow and noise level. In order to provide a robust relationship these measurements were undertaken during adverse wind conditions (i.e. a wind from the source to the receiver).

ANNEX 5 ADDITIONAL GUIDANCE WHEN UNDERTAKING NOISE MEASUREMENTS

A5.1 Traffic noise can vary widely on an hourly, daily and seasonal basis. Care is needed in interpreting any measured data as the effects of varying weather conditions are particularly noticeable when the propagation distance is large. Therefore, in order to estimate the existing noise level within an area, if possible a series of measurements should be taken on several occasions during the assessment period. Where a strong prevailing wind is known to exist between the road and the receiver, the majority of measurements should be taken in those conditions.

A5.2 The weather conditions, especially the wind direction, can have a strong influence on measured noise levels, especially at some distance from the source. Weather conditions should be recorded during all measurement surveys. This could be in the form of a portable measuring device, direct observations on site or information from a reliable calibrated local source.

A5.3 During attended measurements it is essential that notes are made of the main noise sources and any other noise producing activities. It should also be noted whether any events were excluded from the measurement, and the reason for the exclusion. A description, sketch and selection of photographs of all sites should be considered essential.

A5.4 For unattended measurements, if the logging equipment allows, other parameters may be measured in order to help describe the noise climate. These may include the logging of events above a certain threshold or the use of a shorter measurement period to allow removal of suspect data. However, in this situation care must be taken when calculating, for example, an hourly average from several shorter periods. The comparative measurement procedure in Calculation of Road Traffic Noise (CRTN) could also be considered.

A5.5 To fully understand the noise climate of an area it may be necessary to conduct a full 24 hour measurement at some sites. A nighttime measurement should certainly be considered if the nighttime noise level is expected to be within 10 dB of the daytime level.

A5.6 Where the ambient noise level is comprised of a combination of emissions from several undefined sources, for example, a rural setting with occasional noise from machines, aircraft or animals, the assessment of the noise using L_{A10} alone may be inappropriate. It may be more appropriate to determine the ambient noise in these situations by also using the L_{Aeq} index. However, it is important to use this measure averaged over a sufficient time period to ensure the measurement period is representative. In some circumstances this period could be an 18 or 24 hour period.

A5.7 Situations may arise where the ambient noise is either partially or completely dominated by noise other than from road traffic. In such situations it is recommended that the baseline noise levels are measured at representative locations during periods when the non-road traffic noise source is both present and not present. This could be undertaken simultaneously with two noise logging devices, with the non-road traffic noise eliminated from one instrument. Both situations should be described using L_{A10} and L_{Aeq}.

A5.8 Before undertaking measurement work, the advice of the Local Authority Environmental Health Officer should be sought about the availability of existing baseline noise data for the area. However, before using any such data the assessor should be aware of the circumstances of the measurement (e.g. weather conditions, date and time of measurements, noise weightings used).

ANNEX 6 WORKED EXAMPLE

The example given below is intended to provide guidance on the defining of the study area and of a project passing through the assessment processes. The example should not be treated as definitive guidance as most projects will have specific circumstances. This example does not cover an assessment of either vibration or nighttime noise levels.

Description of Project

A bypass of a rural village (Road A) with a single route option to the north of the village. The bypass will introduce a new noise source to a number of dwellings. It is assumed that Road A would be subject to an increase in traffic flow. Road B will be subject to a decrease in traffic volume of more than 20%. Roads C and D will not be subject to an increase of more than 25% or decrease of 20% in traffic flow.

Assessment Procedure

A schematic diagram of the example is shown in Figure A6.1. The project would pass through the screening and scoping stages as there are dwellings within two kilometres of the project boundary. At simple stage the study area would be defined along with the area where noise calculations are to be undertaken.

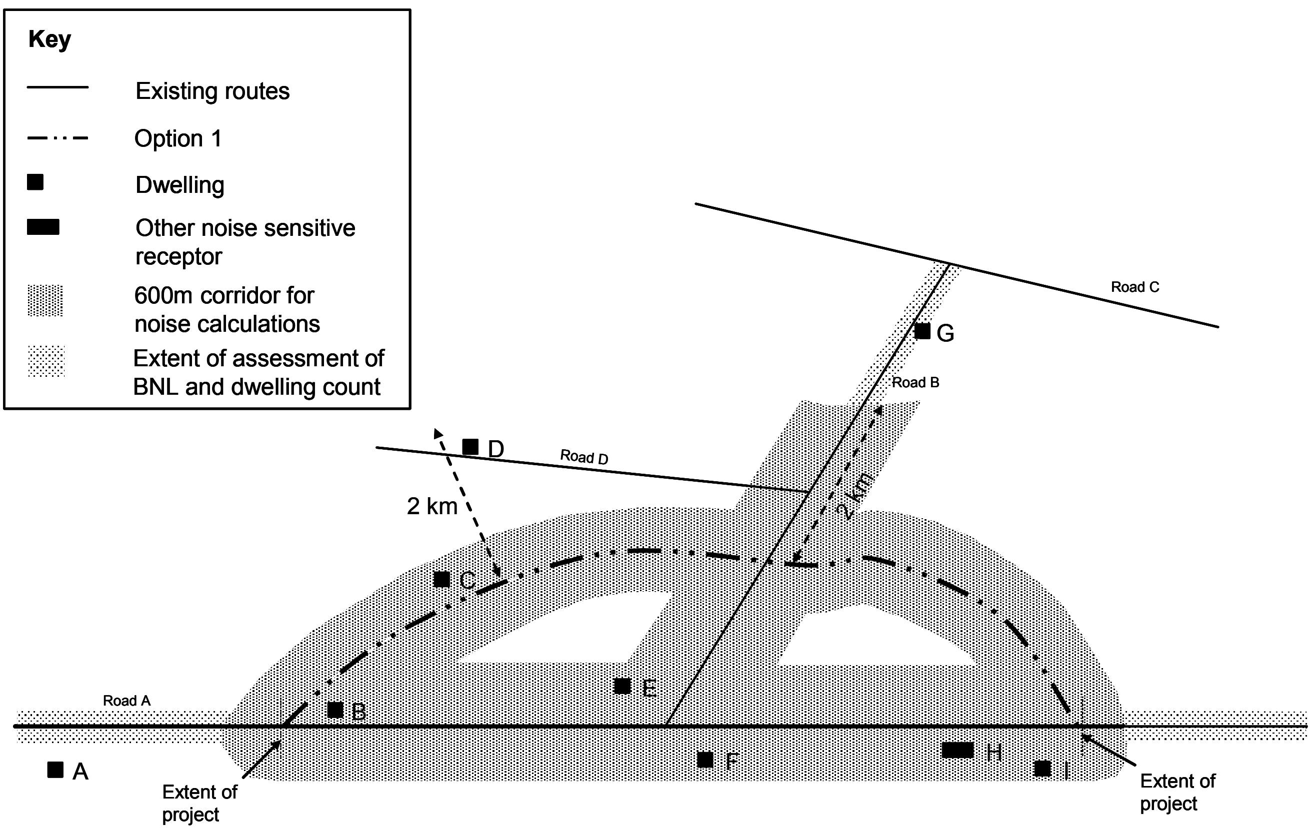

Figure A6.1: Layout for Example

Following the development of a noise model, calculations would be undertaken at the dwellings and other sensitive receptors. These levels are shown in Table A6.1.

Receptor	Do-Minimum		Do-Something	
	Baseline year	**Future assessment year**	**Baseline year**	**Future assessment year**
A	-	-	-	-
B (north)	56.3	56.5	64.1	64.5
B (south)	65.1	65.9	57.7	58.1
C	43.2[1]	43.5[2]	62.7	63.3
D	-	-	-	-
E (north)	55.2	55.4	58.1	58.8
E (south)	64.2	65.0	56.1	56.3
F	63.6	64.4	54.9	55.2
G	-	-	-	-
H - school	64.2	65.0	58.1	58.4
I	58.3	58.8	57.8	58.4

[1] Noise level obtained from measurements.
[2] Estimated from the measured noise level with the addition of noise from predicted increases in traffic flow.

Table A6.1: Noise Levels for Simple Assessment

These noise levels would be free field $L_{A10,18h}$, calculated at a height of 1.5m. No calculations would be undertaken at receptors A, D or G since they are outside the area where calculations would be undertaken.

However, in the area of receptor G, a BNL would be obtained and the number of sensitive receptors within 50 metres of the centreline of the road would be counted. For receptor D, which is within two kilometres of the project boundary, a qualitative entry on the impact from the road project should be given.

The BNL that would be determined for Roads A and B are given below.

	Do-Minimum		Do-Something	
	Baseline Year	**Future Assessment Year**	**Baseline Year**	**Future Assessment year**
Flow (18h)	32,000	34,500	41,000	45,000
Speed (km/hr)	87	86	90	89
% Heavy	12	11	13	12
Surface[1]	0	0	0	0
Gradient	0	0	0	0
BNL	77.7	77.8	79.1	79.3

[1] It has been assumed that there would be no change in the surface correction.

Table A6.2: BNL for Road A

For Road A, the change in the BNL in the baseline year would be 1.4 dB(A) (79.1 – 77.7) and in the future assessment year this would be 1.6 dB(A) (79.3 – 77.7). Although there are no dwellings within 50 metres of the centre line of the affected route, this assessment using BNL should still be undertaken and reported.

	Do-Minimum		Do-Something	
	Baseline year	**Future assessment year**	**Baseline year**	**Future assessment year**
Flow (18h)	3,000	3,050	2,300	2,360
Speed (km/hr)	72	72	72	72
% Heavy	1	1	1	1
Surface[1]	0	0	0	0
Gradient	2	2	2	2
BNL	64.4	64.5	63.3	63.4

[1] It has been assumed that there would be no change in the surface correction.

Table A6.3: BNL for Road B

For Road B, the change in the BNL in the baseline year would be -1.1 dB(A) (63.3 – 64.4) and in the future assessment year this would be -1.0 dB(A) (63.4 – 64.4). Dwelling G would be noted as it is within 50 metres of the centreline of the affected route.

The assessment tables for the calculations at sensitive receptors within 600m of an affected route within two kilometres at simple stage would be as overleaf:

Option/Comparison: Option 1 – Baseline year				
Change in noise level, $L_{A10,18h}$ dB	**Number of dwellings subject to a change in noise level**		**Number of other sensitive receptors subject to a change in noise level**	
	Increase in noise level	**Decrease in noise level**	**Increase in noise level**	**Decrease in noise level**
0				
0.1 – 0.9		1[I]		
1 – 2.9	1[E(north)]			
3 - 4.9				
5 +	2[B(north), C]	1[F]		1[H]
Total	3	2		1

Option/Comparison: Option 1 – Future assessment year				
Change in noise level, $L_{A10,18h}$ dB	**Number of dwellings subject to a change in noise level**		**Number of other sensitive receptors subject to a change in noise level**	
	Increase in noise level	**Decrease in noise level**	**Increase in noise level**	**Decrease in noise level**
0				
0.1 – 0.9	1[I]			
1 – 2.9				
3 - 4.9	1E(north)			
5 +	2[B(north), C]	1[F]		1[H]
Total	4	1		

[Note: The identity of each sensitive receptor is given in the table for the purpose of this and subsequent tables. This level of detail would not normally be expected at a simple or detailed assessment, but clarification of this sort for certain sensitive receptors is encouraged if it aids with the interpretation of the table. This may also assist if further stages of an assessment pass to another Designer.]

Table A6.4: Simple Assessment Tables

The report for the simple assessment would be produced and, since there are increases in noise level on opening of 1 dB(A) and increases in noise of 3 dB(A) in the future assessment year, the project would proceed to a detailed assessment.

For the detailed assessment the noise levels would be recalculated as $L_{A10,18h}$ façade levels, and would also take into account any changes to the design of the project or traffic input parameters (for this example there are assumed to be no changes in traffic input parameters). These levels are shown in Table 6.5.

Dwelling	Do-Minimum		Do-Something	
	Baseline year	Future assessment year	Baseline year	Future assessment year
A	-	-	-	-
B (north)	58.8	59.0	66.6	67.0
B (south)	67.6	68.4	60.2	60.6
C	45.7	46.0	65.2	65.8
D	-	-	-	-
E (north)	57.7	57.9	60.6	61.3
E (south)	66.7	67.5	58.6	58.8
F	66.1	66.9	57.4	57.7
G	-	-	-	-
H - school	66.7	67.5	60.6	60.9
I	60.8	61.3	60.3	60.9

Table A6.5: Noise Levels for Detailed assessment

The calculations for the assessment of nuisance are shown in the table below.

Dwelling	Do-Minimum steady state	Do-Something	
		Steady state	Step change
A	-	-	-
B (north)			41.4
B (south)	2.0		
C	0.1		56.0
D	-	-	-
E (north)			29.8
E (south)	1.9		
F	1.8	-13.7	
G	-	-	-
H	-	-	-
I	0.8	0.1	

Table A6.6: Nuisance calculations for detailed assessment

No calculations would be undertaken at H since this is not a dwelling.

The BNL that would be determined for Roads A and B are given in Tables A6.7 and A6.8.

	Do-Minimum		**Do-Something**	
	Baseline year	**Future assessment year**	**Baseline year**	**Future assessment year**
Flow (18h)	32,000	34,500	41,000	45,000
Speed (km/hr)	87	86	90	89
% Heavy	12	11	13	12
Surface	0	0	0	0
Gradient	0	0	0	0
BNL	77.7	77.8	79.1	79.3

Table A6.7: BNL for Road A

For Road A, the change in the BNL for the future assessment year in the Do-Minimum condition would be 0.1 dB(A) (77.8 – 77.7) and for the Do-Something condition this would be 1.6 dB(A) (79.3 – 77.7). Although there are no dwellings within 50 metres of the centre line of the affected route, this assessment using BNL should still be undertaken and reported.

	Do-Minimum		**Do-Something**	
	Baseline year	**Future assessment year**	**Baseline year**	**Future assessment year**
Flow (18h)	3,000	3,050	2,300	2,360
Speed (km/hr)	72	72	72	72
% Heavy	1	1	1	1
Surface	0	0	0	0
Gradient	2	2	2	2
BNL	64.4	64.5	63.3	63.4

Table A6.8: BNL for Road B

For Road B, the change in the BNL for the future assessment year in the Do-Minimum condition would be 0.1 dB(A) (64.5 – 64.4) and for the Do-Something condition this would be 1.6 dB(A) (79.3 – 77.7). Dwelling G would be noted as it is within 50 metres of the centreline of the affected route.

The Detailed assessment is shown in Tables A6.9 and A6.10.

Project/Option: Do-Minimum baseline year compared with Do-Minimum in the future assessment year																
		Number of dwellings (façade level noise band $L_{A10,18h}$ dB for Do-Minimum condition in the baseline year)														
Change in noise/ nuisance level		**Total**	**< 47.5**	**47.5 - 50.4**	**50.5 - 53.4**	**53.5 - 56.4**	**56.5 - 59.4**	**59.5 - 62.4**	**62.5 - 65.4**	**65.5 - 68.4**	**68.5 - 71.4**	**71.5 - 74.4**	**74.5 - 77.4**	**77.5 - 80.4**	**80.5 - 83.4**	**≥ 83.5**
Increase in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9	5	1[c]					1[I]		3[B(south), F, E(south)]						
	1 – 2.9															
	3 - 4.9															
	5 +															
Decrease in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9															
	1 – 2.9															
	3 - 4.9															
	5 +															
Increase in nuisance level	< 10%	5	1[c]					1[I]		3[B(south), F, E(south)]						
	10 < 20%															
	20 < 30%															
	30 < 40%															
	≥ 40%															
Decrease in nuisance level	< 10%															
	10 < 20%															
	20 < 30%															
	30 < 40%															
	≥ 40%															

Table A6.9: Detailed Assessment Summary Table – Do-Minimum

Project/Option: Do-Minimum in baseline year compared with Do-Something in the future assessment year																
		Number of dwellings (façade level noise band $L_{A10,18h}$ dB for Do-Minimum condition in the baseline year)														
Change in noise/nuisance level		**Total**	**< 47.5**	**47.5 - 50.4**	**50.5 - 53.4**	**53.5 - 56.4**	**56.5 - 59.4**	**59.5 - 62.4**	**62.5 - 65.4**	**65.5 - 68.4**	**68.5 - 71.4**	**71.5 - 74.4**	**74.5 - 77.4**	**77.5 - 80.4**	**80.5 - 83.4**	**≥ 83.5**
Increase in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9	1						1[I]								
	1 – 2.9															
	3 - 4.9	1					1[E(north)]									
	5 +	2	1[c]				1[B(north)]									
Decrease in noise level, $L_{A10,18h}$ dB	0															
	0.1 – 0.9															
	1 – 2.9															
	3 - 4.9															
	5 +	1								1[F]						
Increase in nuisance level	< 10%	1						1[I]								
	10 < 20%															
	20 < 30%	1					1[E(north)]									
	30 < 40%															
	≥ 40%	2	1[c]				1[B(north)]									
Decrease in nuisance level	< 10%															
	10 < 20%	1								1[F]						
	20 < 30%															
	30 < 40%															
	≥ 40%															

Table A6.10: Detailed Assessment Summary Table – Do-Something