RAILWAY NOISE AND THE INSULATION OF DWELLINGS

The report of the committee formed to recommend to the Secretary of State for Transport a national noise insulation standard for new railway lines.
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CHAIRMAN’S FOREWORD

The Members of the Committee gave their time to its work freely and unstintingly. Without this contribution the Report could not have been written and I would like to express my gratitude to them all. I would also like to thank the officials of the Department of Transport and the Department of the Environment who assisted the Committee and made our task much easier. Mr. S. T. Clarke prepared excellent records of our meetings. I am very grateful to all those who submitted evidence to the Committee and provided much information that proved essential in the preparation of a balanced and up to date report. Finally I would like to thank Dr. P. M. Nelson, The Committee’s Technical Secretary, who coped with almost all of the voluminous correspondence our work generated, analysed the evidence for us and contributed from his long experience of transport acoustics. I hope that this report will be a useful contribution to a difficult topic.

C. G. B. Mitchell
On the 23 March 1990 the Minister of State for Public Transport, Mr Michael Portillo, announced the setting up of a Committee to recommend a noise insulation standard for dwellings near new railway lines. The terms of reference for the Committee were

"to recommend to the Secretary of State for Transport a national noise insulation standard (or standards) for the operation of new railway lines which equitably relates to the standard ‘set by regulations for new highways’.

The Committee consisted of the following members:

H. G. Leventhall
(Institute of Environmental Engineering, South Bank Polytechnic and the Noise Council)

G. Llewellyn John
(West Glamorgan County Council)

C. G. B. Mitchell (Chairman)
(Transport and Road Research Laboratory)

P. M. Nelson (Technical Secretary)
(Transport and Road Research Laboratory)

J. B. Ollerhead
(Civil Aviation Authority)

G. A. Parry
(Technica Indecon Ltd)

J. G. Walker
(Institute of Sound and Vibration Research, University of Southampton)

A. V. L. Williams
(British Steel Track Products)

The following officials from the Department of Transport and the Department of the Environment assisted the Committee:

T. D. Arundel
M. R. Broome
S. T. Clarke
S. A. Hall
R. J. Maley
J. W. Sargent

The Committee considered it was important to obtain information from as wide a range of interested parties as possible. In particular, it invited evidence from local authorities, railway operators and from authorities in other countries that had already introduced or made recommendations on standards for insulating houses against noise from new railways. It wanted to determine the rationale which had led to the setting of these standards and to obtain all the relevant scientific data on links between noise from roads and railways and the annoyance or disturbance caused by such noise in different community settings. The Committee therefore advertised its search for information on particular aspects of its work in the national and professional press. It also wrote to local authorities, consultants and organisations likely to have information available. The
Committee is very grateful to those consulted for the wealth of information they provided. A list of contributors is given in Appendix 1.

The recommendations of the Committee are based on an analysis of the scientific evidence on the annoyance and disturbance caused by noise from roads and railways. Having decided what noise level for new railways is equitably equivalent to that used in the Noise Insulation Regulations for new roads, the Committee then looked briefly at the implications of that noise level. Fortunately, it appears not to impose excessive additional costs or operating limitations on new railways, and also seems to lead to noise levels for wayside communities that are about those selected, by local authorities and other countries, as reasonably acceptable. Thus the scientifically derived equitable level should be operationally acceptable to railway constructors and environmentally acceptable to wayside residents.

The report that follows presents the scientific evidence collected by the Committee, an analysis of the evidence and an explanation of how an equitable noise level for new railways was derived, and the Committee’s recommendations to the Secretary of State for Transport.
1 INTRODUCTION

Many transport corridors, like other sites of industrial, commercial or agricultural activity, cause local environmental effects. One of these effects is noise, and in 1973 the Land Compensation Act Part II created powers for improving the sound insulation of buildings affected by public works. These powers were implemented by the Noise Insulation Regulations (1973 and 1975, as amended in 1988), which created a duty to insulate dwellings against traffic noise from new roads and provided discretionary powers to insulate against construction noise. Britain was one of the first countries to introduce legislation for the insulation of dwellings against traffic noise.

There have been relatively few new railways built this century, though extensions and new lines of the London Underground provide an exception. Since the late 1970s a number of projects have involved, or propose, the construction of new lines or the re-activation of abandoned lines. Examples are the diversion of the East Coast Main Line at Selby, the proposed construction of a new rail link from London to the Channel Tunnel, the Docklands light railway, the Tyne and Wear Metro and the Paddington to Heathrow link.

These projects and proposals have raised the question of noise near new railway lines and have identified the need to develop regulations which provide protection from noise for dwellings near new railway lines. This Report is concerned with the available scientific data on the perception of both road and railway noise in the community. It is particularly concerned with establishing a criterion for insulating dwellings against noise generated by new railways which is equivalent, as far as is technically possible, with that already operating for new roads. It is also intended to apply to noise from light railways running on segregated rights of way. The legal position is not clear over the protection of dwellings from noise caused by light railways running on roads, so the Committee has not been able to consider this situation. It may require an amendment to the Noise Insulation Regulations for road traffic. Similarly, the Committee has not considered the case of railways underground because the technical factors concerned are quite different.

In summary, the Report considers how noise levels from roads and railways are measured and expressed. It reviews the general effects of noise on people and examines the specific effects of noise from roads and railways. It presents information on noise standards set by operators, British local authorities and other countries. It discusses the factors that affect the setting of an equitable standard for new railways and summarises the conclusions drawn by the Committee from the evidence available to it. Finally, the Report gives the recommendations of the Committee to the Secretary of State for Transport and explains the evidence and reasoning that led to the recommendations.

2 UNITS FOR MEASURING ROAD AND RAILWAY NOISE

2.1 INTRODUCTION

Noise, often defined as unwanted sound, is caused by small pressure fluctuations in the air. The ear is a very sensitive detector and the range of sound pressures that can be heard is very large. For example, the sound pressure generated at the ear by a jet aircraft at 100 metres could be nearly a million times higher than the minimum sound pressure fluctuation that could be detected by someone with normal hearing. Sound level meters determine the square of the fluctuation in sound pressure, which in turn is proportional to the sound intensity. Thus the intensity of the noise from a jet aircraft at 100 metres is about a million million times that of the minimum that can be detected.
To reduce the range of sizes of the numbers involved in describing the audible range, noise measurements generally use the logarithmic scale of the decibel (dB), based on a reference pressure level of the quietest audible sound. With this scale 0 dB corresponds to the threshold of hearing and 120 dB would represent a painfully loud sound. An increase in sound level of 3 dB anywhere in the scale corresponds to a doubling of the sound intensity. Under ideal laboratory conditions a change of 1 dB within the audible range is just perceptible when the sound consists of a single frequency. For more complicated sounds, which include a broad range of frequencies, it is much more difficult for observers to detect such small changes in level. Typically, for these conditions, changes of 2-3 dB are just noticeable by the average listener. Changes of 5 to 10 dB are clearly detectable in both laboratory and community settings: a change of 10 dB is perceived as an approximate doubling or halving of the loudness of the sound.

The sensitivity of the human ear to different frequencies of sound is not uniform. The ear is most sensitive to sounds in the medium frequency range of 1000 Hz to 6000 Hz. Frequencies below about 20 Hz and above about 20,000 Hz are considered to lie outside the human audible range although the value of the high frequency cutoff varies with age. To take account of this, noise levels measured in particular frequency bands can be weighted to reflect the varying emphasis given by the ear. Several weightings are available but the A-weighting is most widely used, particularly for describing transport noise. Table 2.1 lists A-weighting values corresponding to various frequencies across the audible frequency range.

<table>
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<th>Frequency</th>
<th>Weighting factor</th>
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<tr>
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<td>10000</td>
<td>-2.1</td>
</tr>
<tr>
<td>12500</td>
<td>-4.3</td>
</tr>
<tr>
<td>20000</td>
<td>-6.3</td>
</tr>
</tbody>
</table>

Source: Nelson (ed), 1987

This Report refers to scales and indices which are used to quantify transport noise for the purposes of assessment. It retains the convention of using the word “level” for decibel quantities. A particular level may refer to the instantaneous or short-term average magnitude of the noise, or it may describe a long-term average or a cumulative measure of the noise exposure over a long period of time. By convention, a level is normally symbolised by a capital L. If the level is also weighted, as in A-weighting, then it is usual to add a subscript to signify that the level has been adjusted by the appropriate weighting, i.e. LA. Noise measured as an A-weighted level is in units of A-weighted decibels or dBA.

The word scale is used for measures of acoustical quantities such as the average noise level or the level that is exceeded for a given percentage of the time (see section 2.3 below). Noise indices additionally include other factors such as a weighting for a particular time of day or corrections for the number of noisy occurrences. For example, the day-night index adds 10 dB to all night-time noise levels before taking an average over 24 hours.
2.2 CHARACTERISTICS OF ROAD AND RAILWAY NOISE

Clearly, for both roads and railways the noise characteristics of the traffic stream depend upon the individual contributions from the passing vehicles.

For road traffic, the heaviest trucks tend to produce the most noise and passenger cars the least. At low speed and high engine power, as when accelerating from a junction, the power unit is usually the main noise source. At higher speeds and reduced engine power, the noise generated by the tyres on the road surface becomes more important.

Wayside noise from trains is generated by the interaction of the wheels and rails, the vehicle or locomotive propulsion system, and by radiation from vibrating structures such as steel bridges. It is affected by the speed and length of individual trains. Aerodynamic noise may also be important for high-speed operation (> 300 km/h).

As for road traffic, the noise produced by the wheels rolling on the track is a very important component of the total noise. For trains it is the dominant source of noise over a very wide speed range and, generally, it is only when the train is moving slowly or is stationary that the power plant noise becomes important.

In addition to airborne noise radiated by road traffic and trains, both types of transport can also cause noise problems through groundborne vibration. This is caused by vibration generated at the wheel/rail or road interface which travels through the road or rail support structure and intervening soil to nearby buildings, where it is often perceived as a low frequency rumbling noise or as a mechanical vibration. For railways this tends to occur most often near lines underground, although vibration can also occur with both surface and elevated railways. For roads, the problem does not become serious unless the road surface is in a poor condition.

Road and rail traffic noise differ appreciably in the way the noise is distributed over time. Road traffic noise usually has a fairly uniform sound level interspersed with frequent peaks generated by individual vehicles, whereas railway noise is usually characterised by relatively short periods of noise followed by longer periods of quiet, when the noise returns to the local ambient levels. These differences are illustrated in Figure 2.1 (Parry, 1990a) which shows noise level histories for typical road and railway traffic flows. In Figure 2.1 the two trains causing noise levels of 92 dBA are high speed trains similar to French high speed trains (TGV) while the train causing a noise level of 64 dBA is a local passenger train. The figure refers to a quiet rural area where the background noise level is well below 55 dBA.

Other differences in the temporal distribution of noise occur due to operational factors. On most roads, particularly motorways and other main roads, there is usually a reasonably predictable flow pattern over the 24 hours with, typically, peak flow periods occurring during the morning and evening followed by a substantial reduction in the flow during the night. With railways, commuter travel and other commercial considerations often lead to similar patterns, but since the flow is ultimately determined by the operator, the diurnal flow pattern cannot be assumed.

Table 2.2 shows levels of road traffic noise measured during the day (0600 to 2400 hours) and night (0000 to 0600 hours) at 24 sites that qualified for insulation against noise from new roads. The scales used are $L_{A10}$ (see Section 2.3 below) and the measurements were made in 1980 – 81 by the Building Research Establishment (Sargent, 1990). The average difference between the day and night noise levels was 10 dBA but the actual difference ranged from 4.2 dBA to 17.6 dBA. Similarly, calculated noise levels for current traffic
levels on 18 roads ranging from a highly trafficked motorway (M25) to rural B roads show an average difference in noise level between day and night of 10.9 dBA, with a range from 8.0 dBA to 17.1 dBA (Parry, 1990a).

Because the measurements of noise from road traffic listed in Table 2.2 are for sites where houses qualified for insulation, it is not surprising that at all but one of the sites the noise level $L_{Aeq}$ for the 18 hours between 0600 and midnight exceeded 68 dBA. This is the noise level used in the Noise Insulation Regulations to define whether a house near a new road is eligible for insulation against noise from the road (see also Section 5.2).

Measurements of road and railway noise in Germany (Knall and Schuemer, 1983) give the average difference between day and night levels for roads as 7.2 dBA, with a range from 3 dBA to 15 dBA. For railway noise the average difference quoted is 1.6 dBA, with a range from -2 dBA to +12 dBA. (A negative value indicates that the noise from the railway is greater at night than during the day). In this case the measure of both road and railway noise used is the equivalent noise level $L_{Aeq}$ (see Section 2.3 below) and the day and night periods are not defined, so the results are not strictly comparable to those given above. Moehler (1988) quotes the results of two studies (Holzmann, 1978; PBO, 1983). The differences between $L_{Aeq\, day}$ and $L_{Aeq\, night}$ ranged between 0 and 2 dBA in the case of railway noise and from 8 to 9 dBA in the case of noise from road traffic.

The Committee requested information from British Rail on the day and night noise levels for a number of typical railways in Britain. We were supplied with measurements from 7 sites on one route and one site on another route. These are reproduced in Table 2.3, which shows for each site the 24 hour $L_{Aeq}$, the day and night noise levels $L_{Aeq}$, and the difference between the day and night levels. British Rail have provided separately figures
for a 6 hour night from midnight to 0600, for an 8 hour night from 2300 to 0700, and a 10 hour night from 2200 to 0800. It is clear that the difference between day and night noise levels is very variable. On route 2 there is less difference between day and night noise levels than was found for any of the road sites where measurements were made.

### Table 2.2 Measured Road Traffic Noise for 24 Schemes where houses qualified for insulation – day and night noise levels

<table>
<thead>
<tr>
<th>Site</th>
<th>Daytime noise level 0600 to 2400 hours $L_{A10,18hr}$ dB</th>
<th>Night-time noise level 0000 to 0600 hours $L_{A10,6hr}$ dB</th>
<th>Difference Day – night dBA</th>
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<tr>
<td>01</td>
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<td>55.6</td>
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</table>

Source: Sargent, 1990

### 2.3 SCALES AND INDICES USED FOR ROAD AND RAILWAY NOISE

It can be seen from Figure 2.1 that external noise levels from both roads and railways are far from steady. To take account of the varying nature of the noise level and relate this to the subjective assessment of the noise, many different scales and indices have been developed. The experimental basis for particular scales and indices is reviewed in Sections 3 and 4. The following gives the definitions of some of the more popular measures that have been adopted for transport noise assessment. For non-technical readers, these technical aspects are not essential to an understanding of this Report.

#### 2.3.1 Statistical level, $L_N$

The variability of a fluctuating noise level can be described in terms of its cumulative distribution and various statistical descriptions of this distribution. The most commonly used are $L_{A10}$ and $L_{A90}$, the noise levels in dBA exceeded for 10% and 90% of the time respectively. The $L_{A10}$ has been used over many years for the measurement of road traffic noise in the UK. For the purposes of the Noise Insulation Regulations, which are applicable for road traffic (see also section 5.1), the index used is the arithmetic average of the 18 hourly values of $L_{A10}$ determined over the period from 6 am until midnight on a normal working day. The noise index formed by this average is written $L_{A10,18hr}$. The $L_{A90}$ is often used as a measure of the background noise at a site and is used, for example, in the assessment of industrial noise.
<table>
<thead>
<tr>
<th>Route</th>
<th>Site</th>
<th>24 hour noise $L_{Aeq,24hr}$ dBA</th>
<th>day noise $L_{Aeq,day}$ dBA</th>
<th>night noise $L_{Aeq,night}$ dBA</th>
<th>difference dBA</th>
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**Day 0600 to midnight; night midnight to 0600**

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**Day 0700 to 2300; night 2300 to 0700**

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<th>day noise $L_{Aeq,day}$ dBA</th>
<th>night noise $L_{Aeq,night}$ dBA</th>
<th>difference dBA</th>
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<td></td>
<td>67.3</td>
<td>67.8</td>
<td>66.8</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Source: British Rail (private correspondence)

2.3.2 The maximum noise level $L_{A\text{max}}$

There are various possible applications of the maximum noise level $L_{A\text{max}}$ to the noise from traffic streams. $L_{A\text{max}}$ is the maximum reading given by a sound level meter set to FAST response (with a 0.125 second time constant). It gives an indication of the highest noise produced by the traffic stream. The maximum noise level $L_{A\text{max}}$ is used in several of the standards quoted in Section 5.

The maximum level $L_{A\text{max}}$ for traffic noise could be determined by the noisiest single vehicle or by an infrequently occurring combination of vehicles passing the measuring point during a given measurement period, depending on the conditions selected. In practice, successive measurements of $L_{A\text{max}}$ differ for nominally similar events because of interference by noise from other sources and small differences between nominally identical vehicles. Thus, it is difficult to calculate or measure a value that can be guaranteed to represent the highest noise that would be heard near a railway during a period of several years. However, it is quite practicable to define a maximum noise level that should not be exceeded under given conditions. This could be demonstrated by calculation once the noise emission from the train under standard conditions was known, and measured under controlled conditions so that, for example, the case of an aircraft and train passing simultaneously could be discarded. Any measurements would need to be repeated many times to obtain a representative value for the maximum noise level.
2.3.3 The equivalent continuous sound level, $L_{Aeq}$

The equivalent continuous sound level is defined as the level of that (hypothetical) steady sound that, over the period of measurement, would deliver the same noise energy as the actual intermittent or time varying noise. Using this measure, a fluctuating noise can be described in terms of a single sound level over the same exposure period. It is particularly suitable for describing a noise which consists of occasional short periods of noise between long relatively quiet periods.

The $L_{Aeq}$ is commonly used to describe noise from construction and from industrial premises and is increasingly used to describe transportation noise. In particular, it has been adopted for the assessment of aircraft noise in both the UK and abroad and, by British local authorities, by British Rail and by other national governments, for the assessment of railway noise. When quoting the $L_{Aeq}$ it is important to stipulate the time period over which the measure applies. For example, if the time period is 24 hours the equivalent noise level is usually written $L_{Aeq,24hr}$.

Noise over a period shorter than 24 hours averages to a lower equivalent noise level over the full 24 hours. For example, a noise of N dBA $L_{Aeq}$ over 18 hours, with no noise for the remaining 6 hours, gives a 24 hour $L_{Aeq,24hr}$ of $(N - 1/3)\text{ dBA}$. Similarly N dBA over 12 hours gives $L_{Aeq,24hr}$ of $(N - 3)\text{ dBA}$, N dBA over 6 hours gives $L_{Aeq,24hr}$ of $(N - 6)\text{ dBA}$ and N dBA over 3 hours gives $L_{Aeq,24hr}$ of $(N - 9)\text{ dBA}$. Because the decibel scale is logarithmic, a lower level of noise in the quiet periods of the example above has a surprisingly small effect on the 24 hour noise level. If, in the first example, the noise level in the quiet 6 hours had been $(N - 10)\text{ dBA}$, then the noise level over the 24 hours $L_{Aeq,24hr}$ would be increased by 0.15 dB; a similar noise level over a quiet 12 hours increases $L_{Aeq,24hr}$ by 0.4 dB.

Variants of the $L_{Aeq}$ scale apply weightings to different periods of the day. The most common of these is the day/night equivalent sound level which originated in the USA. This index uses the full 24 hour period but differentiates between day (0700-2200hrs) and night (2200-0700hrs) by adding 10 dBA to the night-time levels. This index is usually symbolised by $L_{dn}$.

A measure related to $L_{Aeq}$, which is used to describe the noise from an individual train or road vehicle, is the single event level, abbreviated SEL or $L_{AE}$. This is the sound level of a hypothetical one second burst of steady noise which would contain the same sound energy as the actual, variable level, noise event.

2.4 CONVERSION OF NOISE INDICES

It will be evident from the previous section that road and railway noise are currently assessed using different scales and indices, the former using the scale of $L_{A10}$ and the latter that of $L_{Aeq}$. To compare the two forms of transport in terms of noise generation it is necessary to be able to convert between the two scales.

A precise relation between the two scales does not exist but the Noise Advisory Council, in their publication "A Guide to the Measurement and Prediction of the Equivalent Continuous Sound Level $L_{Aeq}$" (1978) have suggested the following relation between $L_{A10,18hr}$ and $L_{Aeq,24hr}$ for road traffic:

$$L_{Aeq,24hr} = L_{A10,18hr} - 3 \quad \ldots \ldots \ldots \ldots \quad (1)$$
The 3 dBA conversion is supported by empirical measurements reported by Burgess (1978). Equation (1) is only an approximation for particular traffic flow conditions and it is important to note that this simple rule does not apply for very low traffic flows where the noise level is characterised by infrequent noisy events. For these situations the $L_{Aeq}$ can exceed the value of $L_{A10}$. This difference between the two scales is illustrated by the noise histories shown in Figure 2.1. The values of $L_{Aeq}$ and $L_{A10}$ determined for the road noise are 73 and 76 dBA respectively, while the values for the railway noise are 78 and 70 dBA. The latter is an example of a low traffic flow for which the $L_{Aeq}$ is higher than $L_{A10}$.

Other workers have established slightly different conversion factors between the two indices. For example, Brown (1989) has determined an empirical difference between the two indices of 3.5 dBA for road traffic in Australian cities. Mr R Taylor has put evidence to the Committee of a slightly higher value of 4.0 dBA for the difference. Measurements taken during 1980–81 by the Building Research Establishment at 24 sites give the average difference between $L_{A10,1hr}$ and $L_{Aeq,24hr}$ as 3.7 dBA, with differences ranging from 1.6 dBA to 4.9 dBA (Table 2.4). Measurements at 50 different road sites covering a broad range of traffic flow conditions have been taken by Watts (1984). These data gave a median difference of 3.2 dBA, and a range of differences of 0.5 to 5.6 dBA.

It is therefore justifiable to rewrite expression (1) in the form:-

$$L_{Aeq,24hr} = L_{A10,1hr} - C \quad \ldots \ldots \ldots \ (2)$$

where C will take an average value for road traffic noise, determined by the empirical measurements, of between 3 and 4 dBA.

2.5 MEASUREMENT OF ROAD AND RAILWAY NOISE

Advice on the procedures for the measurement of road traffic noise is contained in the Technical Memorandum “Calculation of Road Traffic Noise” (Department of Transport and Welsh Office, 1988). For the Noise Insulation Regulations for traffic noise it is necessary to determine the noise at a position 1 metre in front of the facade of a building, at a point outside the window or door which is exposed to the highest noise level and which is part of a room of the type that qualifies for insulation against noise. (Under the Noise Insulation Regulations, kitchens and bathrooms, for example, are not eligible for insulation whatever the noise level.) Measurements can, however, be made in the absence of a suitable facade, e.g in an open field, provided a correction is applied to the measured level to allow for reflections from the facade. A correction of +2.5 dBA is included in the statutory method to allow for this effect.

There are no similar guidelines or standards for the measurement of noise from railways, although an international standard exists which is primarily intended for the type testing of rail vehicles (ISO, 1975). Saurenman et al (1982) give examples of the noise and vibration criteria and test conditions used by two United States mass transit authorities in their specifications for new urban rail vehicles. The Centre European Normative technical committee CEN/TC 256 “Railway applications” includes in its programme the specification of test conditions and instrumentation for the measurement of noise emissions from traction and rolling stock.
### Table 2.4 Measured Road Traffic Noise for 24 Schemes where Houses Qualified for insulation L\textsubscript{A10,18hr} and L\textsubscript{Aeq,24hr} Levels

<table>
<thead>
<tr>
<th>Site</th>
<th>Daytime noise level ( L_{A10, 18hr} ) dBA</th>
<th>24 hour noise level ( L_{Aeq, 24hr} ) dBA</th>
<th>Difference dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
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<td>64.9</td>
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<td>24</td>
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</tbody>
</table>

Source: Sargent, 1990

### 3. GENERAL EFFECTS OF TRANSPORT NOISE ON PEOPLE

#### 3.1 INTRODUCTION

The previous section has explained how noise from various sources can be described, and has emphasised the very large range in noise intensity between loud and quiet noises. This section describes the general effects of noise on people and, for completeness, covers the range from exceptional noise levels that can cause physical damage, to lower levels that may make it difficult to sleep or interfere with communication. The following Section 4 considers in detail the effects of noise from roads and railways, and how these compare. In both sections results are given for the disturbance of activities and the annoyance caused by noise. Disturbance is the objectively measurable effect of noise on the performance of a task or activity such as hearing and interpreting speech or getting to sleep. Annoyance is an adverse subjective feeling that people have about noise. This latter effect can only be measured by asking people questions about how they feel. The effects of noise have been reviewed by Bastenier et al (1975). Causes of noise from transport systems, and the effects of this noise, are described in OECD (1986) and Nelson (1987).

#### 3.2 NOISE-INDUCED HEARING LOSS

Noise induced hearing loss is a well-documented occupational risk for workers exposed to high noise levels. It is now widely accepted that there is a finite risk of disability associated with continuous exposure over 10 years to noise at levels greater than 85 dBA \( L_{Aeq} \). The risk increases as the noise level and/or exposure duration increases (Burns and Robinson, 1970; ISO, 1982).
Extremely high sound pressures can rupture the ear drum or cause physical damage to the ear. The threshold of sudden mechanical damage is thought to be at a sound pressure level of around 150 dB or more, which can easily be exceeded in the vicinity of small arms, artillery and pyrotechnics. Such high sound pressure levels are extremely rare in buildings. People who live near railways are not exposed to damaging noise levels of this order from the railway.

3.3 NON-AUDITORY EFFECTS

Occupational noise exposure is a serious problem for a small percentage of society, but everyday noise affects people on a wider scale. There is concern about physiological response to noise. Unexpected loud noises can cause startle responses with associated effects on the autonomic nervous system. Cardiovascular, respiratory, pupil dilation, skin resistance and hormonal responses have all been measured in response to such stimuli. Whilst some workers believe that these responses could possibly be precursors of disease, there is no proven cause and effect relationship. Autonomic system responses to sensory stimulation form part of the natural process of gathering information or preparing for action. Nevertheless, the findings indicate that noise may contribute to stress in certain situations. However, other than noise-induced hearing loss, there appears to be no conclusive evidence of any general adverse effects of noise on health (Taylor and Wilkins, 1987; W.H.O., 1980).

3.4 DISTURBANCE OF ACTIVITIES AND TASKS BY NOISE

Noise disturbs three main groups of activities: firstly, those concerning communication; secondly, those involving work and concentration; and thirdly, those concerning rest and relaxation.

The effects of the first are most easily measured because speech characteristics are acoustically well-defined, whereas rest and relaxation includes biological and psychological factors which are less well defined. Another aspect of disturbance is changing behaviour. Examples are closing windows and moving to a bedroom away from the facade exposed to noise.

Speech communication can be disrupted by intruding noise which interferes with the reception of speech by the ear and brain. The speech affected can be conversation, teaching, use of the telephone, T.V and radio listening, and public address in auditoria or large public spaces. Speech interference relationships have been developed which show that speech can be understood outdoors at one meter distance in an average background level of 65 dBA, whereas indoors the same intelligibility can only be achieved if the background levels are 15 dBA lower (Kryter, 1985). A study of the disturbance caused to school teachers by noise found that above an external road traffic noise level of 60 dBA $L_{A10}$ a higher percentage of teachers considered the classroom to be an unsatisfactory working environment (Sargent et al, 1980). There was little difference between the proportion of teachers bothered by road traffic noise and aircraft noise at a given noise level $L_{Aeq}$.

The effects of noise on rest and relaxation for people who are ill or recuperating cannot so easily be quantified. The individual’s state of mind plays an important role in determining the degree of disturbance, but for rest or relaxation associated with the sick or convalescent, day-time average noise levels of 45 dBA, with night-time levels about 5-10 dBA lower, appear to provide an adequate environment (Kryter, 1985). The Royal National Institute for the Deaf has told the Committee that people with impaired hearing...
are particularly affected by background noise; even a small amount of background noise makes the discrimination of speech difficult for them.

Sleep can be disturbed by intruding noise. People who experience noise at night from sources such as aircraft, road traffic and trains often maintain that their sleep is disturbed and it has been shown, both in the laboratory and in the home, that intruding noise can cause premature changes in sleep stages. Field surveys have also shown that the incidence of reported sleep disturbance increases with increasing noise levels. It is generally accepted that sleep will not be affected by noise at levels below 35 dBA $L_{\text{Aeq}}$ or by events with maximum levels ($L_{\text{Amax}}$) below about 45 to 50 dBA measured indoors.

3.5 GENERAL ANNOYANCE

‘Annoyance’ tends to be used by psycho-acousticians to describe the general feeling of aggravation or vexation caused by noise nuisance. Other expressions linked to annoyance include ‘bother’, ‘disturbance’ and ‘dissatisfaction’ and these are commonly used in studies of noise impact. Annoyance usually refers to general long-term adverse reaction and various methods have been used to express it on a simple numerical scale. General long-term annoyance is perhaps the most convenient and relevant index of the impact of transport noise on the community. It is certainly the most widely used. Annoyance can be defined operationally as a score on a scale of annoyance used by subjects to indicate their disaffection with different types of noise environment. When expressing an opinion, it is up to the individual to aggregate whatever are the particular contributory factors in whatever way seems most appropriate at the time.

If ‘disturbance’ is used collectively to describe the directly intrusive effects of noise, ie distraction, speech interference, awakening etc, then annoyance may be viewed as the subjective end of the noise-disturbance-annoyance chain; annoyance is a subjective reaction evoked by a history of repeated disturbances. Others take the view that annoyance and disturbance are two different but complementary effects of a noisy environment.

It is important to bear in mind the likely importance of a number of attitudinal factors in determining the annoyance caused by noise. Positive or negative attitudes to the noise source have been shown to influence community response. For example, fear of accidents and a belief that the relevant authorities take no account of the wishes of the people are among important factors determining community reactions to transport noise (Fields and Hall, 1987).

Noise can also act as a psychological trigger in that it advertises the presence of an object which may be annoying for reasons other than, or in addition to, the noise itself (eg dirt, danger, severence, etc). In such cases it might still be appropriate to use noise as a surrogate index of community annoyance.

3.6 ANNOYANCE RESEARCH

Psychologists have experimented with numerous methods to quantify annoyance in social surveys. Some have involved a series of questions about reactions to specific disturbances; annoyance scores are calculated from the numbers of ‘yes’ and ‘no’ answers. A more direct approach asks the respondent to rate his or her annoyance on a numerical scale, or into categories such as ‘low’, ‘moderate’, or ‘high’. Current opinion favours the latter approach, which is simpler and gives results which are highly correlated with those of the more convoluted measures of reactions.
Although the direct disturbances caused by noise are strongly governed by physics and physiology, annoyance is a personal response which depends also upon many sociological and psychological factors. Even the physical factors vary considerably from person to person, especially when the effects of varying activity patterns (in time and place) are included; the additional socio-psychological effects make the link between annoyance and noise exposure a very tenuous one.

In the search for noise criteria and standards, many laboratory and field (social survey) studies of subjective reactions to noise have been performed. The former have been used to quantify the noise attributes that cause disturbance (eg its loudness, noisiness, audibility, speech and sleep interfering properties); the latter have led to indices of community annoyance and have also shed light upon the roles of the intervening socio-psychological factors. Predominant among these are people’s environmental expectations and their attitudes to the sources of noise. The two kinds of studies, when coupled with the experience of noise control practitioners, have led to the development of many noise exposure scales and indices for estimating the ‘gross’ impact of different kinds of noise on people in and around their homes.

The first general noise index appears to have been the Composite Noise Rating (CNR) introduced in the USA in 1953 (Rosenblith et al, 1953). Largely by intuition it was hypothesised that public dissatisfaction with intrusive noise depended upon seven factors including average noise level, the presence of discrete frequencies (eg tones and whistles), impulsiveness, repetitiveness, background noise, time of day and history of previous exposure. The CNR formula included terms for each of these factors, significant among which was the combination \( L + 10 \log N \) to account for the contributions of \( L \), the average sound level and \( N \), the number of events heard. CNR was used for many years but, probably because reliable evidence to support particular terms remained scarce, the formula was progressively simplified. In the USA, evolutionary successors to CNR include California’s Community Noise Equivalent Level, CNEL (State of California, undated), and the nationally used Day-Night Sound Level, \( L_{dn} \) (US E.P.A., 1973). What all these indices share is the ‘trade-off’ between noise level for individual events and the total number of noise events identified above – which indicates that the subjective impact of a sequence of sounds is a function of their total sound energy.

The correctness of this assumption has been hard to verify. Probably the first serious attempt to measure the relative importance of average sound level and number of events was the 1961 survey of aircraft noise annoyance at London (Heathrow) Airport commissioned by the Wilson Committee (Wilson, 1963). From the results, that Committee derived the Noise and Number Index,

\[
NNI = L + 15 \log N - \text{constant},
\]

which gives proportionately more weight to numbers than the energy rule and was used for describing noise around British Airports until September 1990, when it was replaced by \( L_{Aeq, 16hr} \) (Department of Transport, 1990).

The existence of more than one noise-number rule has been the subject of much debate and controversy. Uncertainty arises because noise levels and numbers heard tend to be highly correlated in practice (high noise areas generally experience both) and because annoyance is dominated by socio-psychological factors which confound the statistical methods used to determine the effects of individual factors. In 1982 a special survey, part of the United Kingdom Aircraft Noise Index Study, was aimed specifically at the noise-number question (Brooker et al, 1985). The results indicated that the energy rule probably is more realistic than the NNI formula and provides some retrospective support for the many energy-based indices now in common use in many countries.
The widespread adoption of $L_{eq}$ equivalent noise level indices has been largely due to their inherent simplicity and convenience. Since, in terms of annoyance prediction, there appears to be little difference between the various number weightings, it has seemed logical to choose the option of measuring sound energy, which is readily done with an integrating sound level meter.

The correlation between individual annoyance scores and outdoor noise exposure levels (both long-term averages) is usually less than 0.5, sometimes considerably so. This implies that physical noise exposure explains at best 25% of the variance in annoyance indicating that other factors are much more important. These other effects can be suppressed by 'grouping' data, ie by averaging annoyance scores of individuals from restricted noise bands; the results then have much higher correlation coefficients and better illustrate underlying noise-annoyance trends. But, even when the data is grouped in this way it is rare to find any noise exposure index accounting for more than 60% of the variance in the average annoyance scores between sites.

A further problem arises when the results of surveys are compared since considerable differences in the noise level-annoyance curves often result. These differences can occur even for surveys of a single type of transport such as road traffic, as well as for surveys comparing different types of transport where more significant differences might be expected. Examples of the noise level-annoyance relations obtained for different surveys of road traffic and railway noise are given in Section 4 below.

Although part of the observed differences can be attributed to the general uncertainty in determining community reactions to a given noise stimulus, other factors will also play a part. These may include:

i) The wrong choice of noise index – the 'correct' index could be defined as that which minimises differences between the various noise level-annoyance relations.

ii) Differences in the design or administration of the surveys, which then tap different responses from the subjects interviewed. For example, the questions on noise may be presented in different contexts or in different orders in the questionnaires.

iii) Bias, introduced by not matching survey samples, so that the interviewees from the various studies differ in important respects. They may be from different regions with different attitudes, values, socio-economic status, etc.

iv) Differences in reaction induced by different periods of exposure. Populations recently exposed to a change in noise from a particular type of transport may exhibit a different response to populations who have been exposed to a more constant noise level over a long period.

v) Preferences for different types of transport may cause differences in perceptions of what is reasonable or acceptable for a given source. A variation of this is that in an area where there is controversy over a new road or railway, people are likely to be more sensitive to noise and other environmental effects than is usual.

The question as to whether some or all of these factors have an influence on the measured noise level-annoyance relation obtained from a given survey is extremely difficult to
answer. This uncertainty poses a significant problem when attempting to identify the level of noise produced by one form of transport which would produce the same degree of annoyance as noise from another, since this requires the identification of comparable points on the noise level-annoyance curves for the two modes.

3.7 SLEEP RESEARCH

Research into the effects of noise on sleep has traditionally divided into two main streams. First, scientists have conducted many physiological experiments with instrumented experimental subjects both in the laboratory and in their own homes. They have discovered that intruding noises can cause changes in sleep so that individuals might spend less time in the deeper sleep stages during the night. Second, social statisticians have explored the relationships between sleep disturbance as reported in social surveys and noise exposure as measured or predicted by acousticians. There tends to be rather poor correlation between reported awakenings and recorded intrusive events such as aircraft flyover noises and, similarly, rather poor correlations between reported sleep quality and observed behaviour such as awakening or changes in sleep stage patterns. However, it is possible to infer that intrusive noise does not affect sleep at all at indoor levels below about 35 dBA, and also that reported sleep disturbance is not significantly increased by transport noise, for example, until the exterior noise levels exceed approximately 82 dBA (Vallet, 1987; Rice and Morgan, 1982).

These remarks on sleep disturbance must be qualified by reference to the particular sensitivity of some individuals to recognisable noises during the process of dropping off to sleep. This phenomenon is more likely to be due to the distracting effect of the sound than any simple relationship between noise level and arousal level. However, this does not mean that this effect should be discounted when making a practical assessment of a reported noise problem.

There are many factors that affect sleep quality. About 20% of the population have sleeping difficulties which are totally unrelated to noise. Age, sex, attitudes and health factors override the impact of noise-induced sleep disturbance. Background noise levels, habituation, bedroom location, time of night and the character of any intruding noise also influence sleep quality. Bearing this in mind it is unrealistic and often impractical to set noise limits to ensure that sleep will not be affected in any way. A criterion set at a level that takes account of the mediating variables may be more acceptable.

Rice and Morgan (1982), in a comprehensive synthesis of both field and laboratory studies, suggest that sleep disturbance is significant when 25% of the population are likely to suffer some disturbance from all causes; they have suggested source specific outdoor noise levels at which these effects might be identified. These facade equivalent noise levels $L_{Aeq}$ are 55 dBA and 60 dBA respectively for steady noise and road traffic and for aircraft and trains. The corresponding maximum noise levels $L_{Amax}$ are 80 dBA, 75 dBA and 85 dBA for steady noise, road traffic, and for aircraft and trains.

Rice and Morgan state that these limits should be interpreted as meaning that noise disturbance of sleep by trains or aircraft may be expected to become significant once the outdoor night-time (2200-0700) $L_{Aeq}$ exceeds 60 dBA, but that it could occur at a lower value of $L_{Aeq}$ if there are more than 20 events per night for which the $L_{Amax}$ of individual events exceeds 85 dBA. Very noisy events should be avoided between 2200 and 2400 hrs, the time at which adults are usually getting to sleep. Children would normally be getting to sleep earlier in the evening, so for their sake very noisy events should be avoided earlier in the evening.
4. EFFECTS OF NOISE FROM ROADS AND RAILWAYS

4.1 INTRODUCTION

4.1.1 General

This Report is concerned with establishing what noise level caused by a railway has the same effect on people as does the noise level of 68 dB $L_{A10,1B}$500 caused by road traffic. This is the level at which dwellings are insulated against the noise from a new road (see Section 5.2.1). Section 4.2 examines available research results to see whether railway noise causes more or less disturbance to communications and to sleep than road noise at the same level. Section 4.3 considers what noise level from a railway causes the same amount of annoyance as would a given noise level from a road. Any difference in the noise level to cause the same reaction in terms of the percentage of people annoyed or disturbed can be described as a "noise differential". Because annoyance and disturbance are different effects, it is to be expected that the differentials between road and rail noise for equal annoyance and disturbance will be different. Furthermore, the differentials depend on the noise scale adopted; a different scale might lead to different differentials.

There have been many studies of the annoyance and the disturbance caused by noise both from road traffic and railways. These studies generally differ in their design, in the measurements taken and in the analysis methods employed. Section 3.6 has noted the difficulties and uncertainties in comparing the results of one-survey with another and, consequently, in determining noise levels which cause the same annoyance for the different sources.

Some surveys have been designed specifically to compare people's reactions to noise from different sources. In most of these studies attempts have been made to minimise differences between the questionnaires and the sample populations interviewed for each type of noise. Examples are the studies performed by Holzmann (1978), Heintz et al (1980), Hall et al (1983), Kastka et al (1983), Knall and Schuemer (1983), Moehler and Knall (1983), PBO (1983) and Moehler et al (1986).

Many other studies have attempted to compare the effects of two forms of transport by combining surveys of the effect of one type of noise with a secondary re-analysis of previous surveys of the other type of noise. These studies include those by Fields and Walker (1982a, 1982b) (which has been recognised by many as the seminal study of the subject, against which others are compared) and Peeters et al (1983). Three other studies by Ahrlin and Rylander (1979), Berry (1983) and Sorenson and Hammar (1983) were limited to the re-analysis of previous survey data.

The sample sizes and geographic coverage of the studies vary considerably. The national survey of railway noise and nuisance by Fields and Walker (1982b) achieved a sample of 1453 interviews and over 2000 noise measurements spread over 75 study areas in Great Britain. A national survey of the environmental effects of road traffic in England obtained 6017 interviews (Morton-Williams et al, 1978) and noise measurements were taken at 1040 dwellings in 150 local authority areas (Harland and Abbott, 1977). The studies reported by Moehler, Knall, Schuemer and Planungsbüro Obermeyer München (PBO) used samples of up to 1500 people from 20 areas of Germany. The study by the Groupe de Travail: bruit d'origine ferroviaire (1988) involved interviews with 670 residents in 10 areas of France. Several of the other studies used much smaller numbers of interviews and limited interviews and measurements to one or two small areas. These latter surveys cannot be considered to be as statistically reliable or as representative as those noted.
above. The Committee felt that these could not be given the same weight as the former, more substantial, studies.

4.1.2 The choice of a noise scale for railway noise

The acoustic scale $L_{A10}$ that is used in Great Britain for road noise is not suitable for railway noise because on many railways noise from trains is not audible for as much as 10% of the time. In these conditions $L_{A10}$ measures some aspect of the background noise rather than the noise from the railway.

A number of studies have been undertaken to determine which noise scale is best for describing railway noise in assessing the annoyance and disturbance that it causes, and others have made similar examinations of road traffic noise and annoyance. Fields and Walker (1982b) compared the relative explanatory power of the scales or indices $L_{eq}$, $L_{dn}$, CNE, NNI, CNR and NEF in the context of annoyance by railway noise. They found that the commonly used $L_{Aeq,24hr}$ was more highly related to annoyance than any of the other indices, but that the differences could not be specified precisely enough to reject the other indices.

In a review of previous work, Moehler (1988) noted that most of the studies had used $L_{Aeq}$ as the acoustic index. Several studies (Andersen et al., 1983; Auberry, 1975; Fields and Walker, 1982b; Ohrström et al., 1980; Peeters et al., 1983; Sorensen and Hammar, 1983; and Vernet, 1979) found that $L_{Aeq}$ correlated better with general annoyance than did $L_{Amx}$. Almost all the noise standards or criteria listed in Section 5 use $L_{Aeq}$ as the acoustic index, usually measured over 24 hours.

Recent work in France (Groupe de Travail: Le bruit d’origine ferroviaire, 1988) suggested that noise nuisance from railways during the day was best described by $L_{Aeq}$ for the period 0800 to 2000 hours. For the evening the best indicator was found to be the total time between 1915 and 2215 hours that the noise level exceeded 70 dBA, but $L_{Aeq}$ for that period was almost as good and more practical to use. For night-time, the best indicator was the number of trains causing maximum noise levels $L_{Amx}$ greater than 80 dBA.

In the light of the evidence that $L_{Aeq}$ is (a) at least as good a predictor of railway noise annoyance as any available alternative measure, and (b) is widely accepted and used for rating many kinds of environmental noise, the Committee had no hesitation in recommending the equivalent noise level, $L_{Aeq}$, as the appropriate measure to use for railway noise.

4.2 COMPARISON OF THE DISTURBANCE CAUSED BY ROAD AND RAILWAY NOISE

Moehler (1988) has reviewed numerous studies that compare the annoyance and the disturbance to various activities caused by noise from roads and railways. He observed that the most disturbing effect of railway noise is interference with communication (using the telephone, teaching, speaking, listening to radio, etc.), followed by disturbance of rest and relaxation and, lastly, disturbance of sleep. Andersen et al. (1983) concluded that few people reported interference with sleep, and even fewer attributed it to the noise of rail traffic.

The differential between railway and road noise levels for equal disturbance depends on the activity being disturbed. Table 4.1 summarises the results of a number of studies. For interference with sleep or disturbance at night, rail noise is more tolerable than road noise,
with differentials ranging from 4 to 20 dBA; likewise, in terms of general disturbance and interference by day, railway noise is more tolerable than road noise, with differentials ranging from 0 to 10 dBA. On the other hand, for interference during the day or with communication, railway noise is equally or less tolerable than road noise, with differentials from -4 to +2 dBA out of doors and -16 to 0 dBA indoors; most lie in the range -4 to 0 dBA. (A positive differential means railway noise is more tolerable than road noise, a negative differential the reverse). Finally, for disturbance to indoor leisure activities, railway noise is more tolerable than road noise, with a differential of 0 to +12 dBA; conversely for outdoor leisure activities, railway noise is marginally less tolerable, with a differential of -1 to 0 dBA.

<table>
<thead>
<tr>
<th>Study</th>
<th>Disturbance reaction</th>
<th>Noise level differential</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>dBA $L_{Aeq,24hr}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>or $L_{Aeq,night}$</td>
</tr>
<tr>
<td><strong>Daytime effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holzmann (1982)</td>
<td>Interference during day</td>
<td>+5 to +10</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>- ve</td>
</tr>
<tr>
<td>PBO (1983)</td>
<td>Interference during day</td>
<td>0 to +4</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>-4 to -1</td>
</tr>
<tr>
<td>Knall et al (1983)</td>
<td>General disturbance, day</td>
<td>+2 to +6</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>-4 to 0</td>
</tr>
<tr>
<td></td>
<td>Disturbance, outdoor leisure</td>
<td>-1 to 0</td>
</tr>
<tr>
<td>Moehler (1985)</td>
<td>Communication indoors, windows closed</td>
<td>-16 to -7</td>
</tr>
<tr>
<td></td>
<td>Communication indoors, windows open</td>
<td>-3 to 0</td>
</tr>
<tr>
<td></td>
<td>Communication outdoors</td>
<td>-3 to +2</td>
</tr>
<tr>
<td></td>
<td>Indoor rest and leisure, windows closed</td>
<td>0 to +4</td>
</tr>
<tr>
<td></td>
<td>Indoor rest and leisure, windows open</td>
<td>+5 to +12</td>
</tr>
<tr>
<td>Moehler et al (1986)</td>
<td>General disturbance, day</td>
<td>+1 to +7</td>
</tr>
<tr>
<td></td>
<td>Communication</td>
<td>-4 to -1</td>
</tr>
<tr>
<td></td>
<td>Disturbance, outdoor rest and leisure</td>
<td>-1</td>
</tr>
<tr>
<td></td>
<td>Disturbance, indoor rest and leisure</td>
<td>+1 to +7</td>
</tr>
<tr>
<td><strong>Night-time effects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holzmann (1978)</td>
<td>Interference at night</td>
<td>+6 to +11</td>
</tr>
<tr>
<td>Heintz et al (1980)</td>
<td>Interference with sleep</td>
<td>+4 to +20</td>
</tr>
<tr>
<td>PBO (1983)</td>
<td>Interference at night</td>
<td>+9 to +11</td>
</tr>
<tr>
<td>Vernet et al (1983)</td>
<td>Interference with sleep</td>
<td>+ ve</td>
</tr>
<tr>
<td>Knall et al (1983)</td>
<td>Disturbance to sleep</td>
<td>+12 to +14</td>
</tr>
<tr>
<td>Moehler et al (1986)</td>
<td>General disturbance, night</td>
<td>+7 to +8</td>
</tr>
<tr>
<td></td>
<td>Disturbance to sleep</td>
<td>+12 to +14</td>
</tr>
</tbody>
</table>

+ ve — people more tolerant of railway noise than road noise
- ve — people less tolerant of railway noise than road noise

4.3 COMPARISON OF THE ANNOYANCE CAUSED BY ROAD AND RAILWAY NOISE

4.3.1 The relation between noise level and annoyance

Annoyance, being a subjective response, is more difficult to measure than disturbance, as was explained in Section 3. A number of papers give graphs or tables that show how the proportion of people annoyed by noise varies with the noise level. Figure 4.1 gives an example of one such study from France (Groupe de Travail: le bruit d'origine ferroviaire,
1988). In this figure, separate results are shown for annoyance over 24 hours, daytime and evening. In each case, results are given separately for the percentage of people “very annoyed” (or possibly “very bothered” or “very irritated”; the original is “très gênés”) and “very annoyed and annoyed” (très gênés et gênés). The three lines on each graph show the probable result and the band within which the researchers are confident the result lies.

There are great difficulties in comparing the results from different surveys and any such comparisons must be treated with considerable caution. It is not even clear that the same degree of annoyance is implied by the French word “gêné”, the German words “Störung” and “Belästigung” and the English word “annoyance”. We have been advised that “gêné” implies less annoyance than “annoyed”, and corresponds more to “irritated” or “put out”. Any differences in the perceived meaning of the question could influence the annoyance response measured.

(a) Overall nuisance during 24 hours.

(b) Nuisance during the day, 0800 to 2000 hours.

(c) Nuisance during the evening, $L_{Aeq, (19h 15 - 22h 15)}$

Fig. 4.1 Nuisance due to noise from railways. Noise level is partial $L_{Aeq}$

(Groupe de travail: bruit d'origine ferroviaire, 1988)
Some indication of the difficulties may be obtained by comparing the noise level-annoyance curves measured in different social surveys. Examples are given in Figures 4.2 for populations experiencing moderate annoyance (ie both highly annoyed and only moderately annoyed), and Figure 4.3 for those severely annoyed. The preparation of the figures has required some re-analysis of the research data to harmonise the noise level measures and curve-fitting procedures.

Although the rate of growth of annoyance with noise level is similar in all cases, no consistent difference between the road and rail results is apparent; the two sets of curves display no particular order. The reasons can only be speculated upon. The results may
<table>
<thead>
<tr>
<th>Source</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Harland, 1977 National Survey</td>
<td>Very much or quite a lot bothered</td>
</tr>
<tr>
<td>2 Rylander et al, 1976</td>
<td>Very annoyed</td>
</tr>
<tr>
<td>3 Hall et al, 1981</td>
<td>Highly annoyed</td>
</tr>
<tr>
<td>4 Fields and Walker, 1980: all trains</td>
<td>Very annoyed</td>
</tr>
<tr>
<td>6 Fields and Walker, 1980: diesel and 3rd rail electric only</td>
<td>Very annoyed</td>
</tr>
<tr>
<td>6 Fields and Walker, 1980: overhead electric only</td>
<td>Very annoyed</td>
</tr>
<tr>
<td>7 France, 1988 Groupe de Travail</td>
<td>Very annoyed</td>
</tr>
<tr>
<td>8 Anderson et al, 1988</td>
<td>Strongly annoyed</td>
</tr>
</tbody>
</table>

**Fig. 4.3** Severe annoyance and noise levels from roads and railways
reflect different cultures and public perceptions, attitudes and reactions at different times in different countries. On the other hand, they may be wholly attributable to different survey methodologies, semantic differences, or to sampling fluctuations or bias. They are probably influenced by all these factors, and possibly by others besides.

Any variation in the noise level-annoyance curves which might be attributed to region, culture or semantics might be reduced by confining attention to the British results incorporated in Figures 4.2 and 4.3. For the severe annoyance category (Figure 4.3), railway noise as determined by Fields and Walker (1980) for all trains appears marginally more acceptable than road noise as determined from the National Survey (Harland and Abbott, 1977). A re-analysis of the data shows a difference of about 2 dBA in favour of rail, although the more detailed analysis originally conducted by Fields and Walker showed a larger difference. When the data for diesel and third rail electric powered railways are plotted separately it would appear that these trains are more annoying than road noise over the same range of $L_{Aeq}$ while overhead powered electric trains are markedly less annoying.

4.3.2 Comparisons of the annoyance caused by noise from roads and railways

Despite the difficulties mentioned above, several authors have attempted to compare the annoyance caused by road and railway noise. Table 4.2 compares the results of different studies reviewed by Moehler (1988) and some additional ones not included in that review.

Table 4.2 shows that the majority of the surveys found that railway noise is less annoying than road noise. The differential in favour of rail varies between surveys within the range of 3 to 15 dBA at levels of 60 to 70 dBA, though most found values between 4 and 9 dBA. At noise levels of 50 to 60 dBA the differential was small or zero. Two relatively small studies reviewed by Moehler (1988), one relying wholly on secondary analysis of previous survey data and the other wholly on laboratory studies, produced the result that railway noise was more annoying than road noise (Berry, 1983 and Öhrström et al, 1980).

One study in which identical questionnaires were used to derive responses to road and railway noise is reported by Moehler and Knall (1983). Figure 4.4 from this study gives separate curves of annoyance against noise level for road traffic and railways, and for day (0600-2200 hrs) and night (2200-0600 hrs). The data were obtained from surveys conducted in 14 areas in West Germany, half of which were exposed to predominantly railway noise and half to road noise. This study showed that during the day there was little difference in the reactions to road and railway noise, whereas at night and at noise levels of $L_{Aeq, night}$ of about 70 dBA, rail noise was less annoying.

A subsequent study by Moehler et al (1986) surveyed the noise annoyance of a total of 1500 subjects in 20 areas. In seven areas the noise was predominantly from railways, in seven from road traffic, and in six areas the levels of noise from roads and railways were similar. The study looked at aspects of annoyance that were relevant to day and night. The results are summarised in Table 4.3. The differential in favour of rail for overall daytime nuisance was 3.4 dBA for noise levels of 60 to 70 dBA, and -0.4 dBA for levels of 50 to 60 dBA. The overall differential at night, again in favour of rail, was 9 to 11 dBA and was not very sensitive to the noise level.

Kumagai et al (1975) compared the results of three Japanese surveys; two were concerned with railway noise and the other was concerned with road noise. All three surveys gave very similar results. Conventional railway noise was found to cause the greatest annoyance, followed closely by road noise and, lastly, noise from the Shinkansen railway. Nakamura and Yoshida (1990) have reviewed five surveys of the percentage of people
disturbed by railway noise. Because of the conciseness of the paper it is not possible to establish all the details of the work done, but the authors comment particularly that they found more annoyance at a given level of railway noise than did Fields and Walker; this could be a result of differences of survey techniques, of semantic differences or cultural differences.

<table>
<thead>
<tr>
<th>Study</th>
<th>Noise level differential, dBA $L_{Aeq}$, 24hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noise levels 50 to 60 dBA</td>
</tr>
<tr>
<td>Studies known to use large samples over a wide area</td>
<td></td>
</tr>
<tr>
<td>Fields &amp; Walker (1982a)</td>
<td>+1</td>
</tr>
<tr>
<td>PBO (1983)</td>
<td>+2</td>
</tr>
<tr>
<td>Knall et al (1983)</td>
<td>+1</td>
</tr>
<tr>
<td>Moehler et al (1986)</td>
<td></td>
</tr>
<tr>
<td>Other studies (not necessarily less reliable)</td>
<td></td>
</tr>
<tr>
<td>Berry (1983)</td>
<td></td>
</tr>
<tr>
<td>Flindell (1983)</td>
<td></td>
</tr>
<tr>
<td>Holzmann (1978)</td>
<td>+7 to +11</td>
</tr>
<tr>
<td>Katzka et al (1983)</td>
<td>0 to +4</td>
</tr>
<tr>
<td>Heintz et al (1980)</td>
<td></td>
</tr>
<tr>
<td>Öhström et al (1980)</td>
<td></td>
</tr>
<tr>
<td>Pecters et al (1983)</td>
<td></td>
</tr>
<tr>
<td>Kumagai et al (1975)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-3 conventional train</td>
</tr>
<tr>
<td></td>
<td>+1 high-speed train</td>
</tr>
</tbody>
</table>

$+\text{ve} -$ people more tolerant of railway noise than road noise

$-\text{ve} -$ people less tolerant of railway noise than road noise

Note: Some of the second group of studies are known to have used small samples or sampled from a small geographical area. For others of the second group of studies insufficient details are known to assess the sample size or geographical coverage.

There seems to be a slight tendency for more recent studies to measure smaller differentials than earlier studies, although this certainly cannot be considered to be statistically significant. Knall and Schuemer (1983) stated that "the overall road/rail difference of 4.4 dBA found in this study is somewhat lower than that reported by Heimerl and Holzmann (1978), and distinctly lower than that reported by Fields and Walker (1978)." Moehler (1986) obtained an overall daytime road/rail difference of 1.5 dBA, and a difference for daytime disturbance of 4.2 dBA. All these differentials were measured over a range of noise levels of 50 to 70 dBA $L_{Aeq}$.

Hall (1984) carried out a comprehensive review of then available studies of annoyance caused by noise from roads and railways and concluded that:

"there is some evidence that the annoyance response function for rail noise is lower than for road noise but the evidence is not strong enough to reject the hypothesis that it is all a random variation about an 'average' response".

Hall further concluded that a single curve, showing the percentage of people annoyed by noise at different noise levels, fitted through the data for both roads and railways was the best estimate that could be made in 1984 of the annoyance caused by noise from surface transport.
Thus almost all studies seem to indicate that railways are less annoying than roads at a given noise level in the range 60 to 70 dBA $L_{Aeq}$. However, Figure 4.4 from one of the apparently most reliable studies suggests there is little difference in daytime annoyance. Two of the smaller studies showed noise from railways to be more annoying than that from roads. Almost all studies report rail/road differentials at the lower end of the range found by Fields and Walker (1982a and 1978). The differential in noise levels for equal annoyance is probably 3 to 5 dBA in favour of railways, but the scientific evidence is not sufficiently precise to be completely certain it is not zero.

Table 4.3 Differences Between Levels of Road and Railway Noise for Equal Annoyance and Disturbance

<table>
<thead>
<tr>
<th>Effect</th>
<th>Difference between road and railway noise levels for equal effect, dBA $L_{Aeq}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noise levels 50 to 60 dBA</td>
</tr>
<tr>
<td>24 hour effects</td>
<td></td>
</tr>
<tr>
<td>General annoyance</td>
<td>+0.8</td>
</tr>
<tr>
<td>Bother, worry</td>
<td>+1.3</td>
</tr>
<tr>
<td>Daytime effects</td>
<td></td>
</tr>
<tr>
<td>General disturbance</td>
<td>+1.3</td>
</tr>
<tr>
<td>Indoor disturbance, rest and leisure</td>
<td>+0.8</td>
</tr>
<tr>
<td>Outdoor disturbance, rest and leisure</td>
<td>-0.7</td>
</tr>
<tr>
<td>Interference with communication</td>
<td>-1.3</td>
</tr>
<tr>
<td>Metabolic and involuntary reactions</td>
<td>-0.9</td>
</tr>
<tr>
<td>Overall daytime</td>
<td>-0.4</td>
</tr>
<tr>
<td>Night-time effects</td>
<td></td>
</tr>
<tr>
<td>General disturbance</td>
<td>+6.9</td>
</tr>
<tr>
<td>Disturbance to sleep</td>
<td>+11.9</td>
</tr>
<tr>
<td>Overall night-time</td>
<td>+9.0</td>
</tr>
</tbody>
</table>

+ Response to railway noise less than to road noise
- Response to railway noise more than to road noise

4.3.3 Situations and types of trains studied

Most of the studies examined in this section measured the effects of ‘free-flowing’ trains. There have been three studies of the effects of shunting yards (Heintz et al, 1983; de Jong, 1983; and Dixit and Reburn, 1980). These studies showed that yard noise is generally more annoying than the noise of free-flowing trains, but it has not been considered by the Committee.

Four field studies found that goods trains cause slightly more annoyance than passenger trains (Andersen et al, 1983; Fields and Walker, 1982b; Holzmann, 1978; and Peeters et al, 1983). In addition, Kumagai et al (1975) report that relatively higher levels of complaint occurred along the freight-only line running through the city of Sendai in Japan. However, in a laboratory study, where recordings of noise were replayed to a jury of listeners, it was found that there was no difference in reaction to the noise of goods trains, passenger trains and high-speed trains (TGV) at the same noise level $L_{Aeq}$ (Moehler, 1988). Moehler suggested that, despite the limitations imposed by the laboratory simulation, the differences observed in annoyance for the field studies were
Fig. 4.4 Annoyance caused by day and night noise from road and railway traffic (Moehler and Knall, 1983)

adequately explained by the differing values of noise level $L_{Aeq}$ for the different types of trains.

Fields and Walker (1982b) found that, at the same $L_{Aeq}$, diesel and third rail electric trains were significantly more annoying than railways with overhead electric power. The difference between diesel and electric trains was thought to be due to higher levels of low frequency noise from the former, but no satisfactory explanation could be found to account for the difference between third rail and overhead electric trains. It may be significant that the latter were generally more modern stock running mainly on welded track.

Knall and Schuemer (1983) found that the differential between road and railway noise was less in rural areas than in urban areas. This study sampled 14 areas, seven of which were urban and the rest rural (defined as communities with populations less than 20,000). For most of the measures of both annoyance and disturbance used in this study “the mean
difference between the annoyance by road and rail traffic noise is greater in urban than rural areas. Whereas in urban areas subjects are much more annoyed by road than by rail traffic noise, in rural areas the road/rail differences are relatively small." The more recent study by Moehler et al (1986) did not confirm this difference between rural and urban areas.

4.4 STUDIES IN PROGRESS AND OTHER RESEARCH ISSUES

One question over the results quoted above is that almost all of them are based on surveys near existing roads or railways. It has been suggested that these may not apply to noise from new roads and railways. Only one study has examined people's reaction to a new railway, which used surveys before, three months after and 18 months after the opening of a new railway line (van Dongen and van den Berg, 1983). This was undertaken under rather special-conditions and Moehler (1988) considers that its main finding, that habituation to the new level of railway noise does not occur, cannot be applied to other areas. However, research currently underway at TRRL on the reactions of people to changes in noise from road traffic is also showing that over about 18 months there is no habituation to either increases or decreases in traffic noise. This research also suggests that people's reaction to a change in noise level is greater than would be deduced from measurements of reaction in a variety of unchanging conditions.

Research in progress in France should help to answer some of the questions associated with new railways. One project is examining people's reaction to noise from a recently opened high-speed (TG V) railway line. This should also provide evidence on the relative annoyance and disturbance caused by high-speed and conventional trains. In the longer term it should help to answer the question whether reactions to noise from existing railways give a true measure of reactions to noise from new railways.

Another project is surveying the reactions of groups of people exposed at home to noise from roads, noise from railways and noise from roads and railways (Vernet et al, 1989). The first results from this project are rather complicated. Of the people surveyed who experience higher noise levels from roads than railways, 55% claim to be very disturbed by train noise. This suggests either that people living along a railway line attribute to train noise the nuisance caused by road noise, or that the effects of road and railway noise enhance each other in causing nuisance. The sample for this study included people living near four different railway lines. These lines carry, respectively, suburban and main line passenger trains, high-speed (TG V) passenger trains, goods trains and mixed passenger and goods trains. When it is complete it should provide good evidence on the relative annoyance and disturbance caused by different types of train.

In Britain there are no studies currently planned to examine the differences in annoyance and disturbance caused by noise from new roads and new railways. This section has shown the uncertainty of these differences. Now that new railways and new light rail systems are likely to be built, as well as new roads, the Committee consider it would be sensible to take any opportunities that allow these differences to be measured, to improve our knowledge of them.

4.5 ACCEPTABLE LEVELS OF NOISE FROM ROADS AND RAILWAYS

Although the Committee's terms of reference did not specifically include the acceptability of noise from railways it was inevitable that evidence was received on the acceptability of various noise levels. Much of this evidence has been reviewed in Section 4.2 and 4.3 above, and further evidence is reported in Section 5 which summarises standards adopted by other countries, by local authorities for planning purposes and by railway operators.
This section summarises existing scientific evidence on the acceptability of noise from
different types of transport.

Moehler (1983) reports that, on the basis of a number of studies, there is no critical noise
level beyond which noise from railways becomes intolerable. This conclusion is based on
the lack of agreement between the various studies of the value found for an acceptable
limit for the noise level. Walker (1988) reviewed several studies carried out in the UK and
suggested that railway noise becomes barely tolerable when the LAeq,24hr level reaches 74
dBA, i.e. with 20% or more of the population highly annoyed, and is acceptable at a level
of 65 dBA, which corresponds to 10% or less of the population highly annoyed. Walker
proposed that to maintain the quality of the environment the maximum tolerable noise
level be reduced to 70 dBA LAeq, to give less than 20% of people highly annoyed.

These exposure levels are consistent with Schulz’s (1978) curve of the percentage of
people highly annoyed by noise, developed from 11 surveys of responses to noise from
various transport modes. This gives 8% highly annoyed at an Ldn of 60 dB, 25% at 70 dB
and 52% at 80 dB. Ashdown Environmental (1989) quote results from a number of
studies of railway noise and these are reproduced in Table 4.4. There is considerable
scatter, but there appears to be no significant reaction below an LAeq,24hr of about 54 dBA.
About 20% of people are annoyed or seriously annoyed at a level of 63 dBA, 50% at 72
dBA and almost everybody by 80 dBA. This is also supported by a French study that
found that at noise levels below 60 dBA annoyance was small, though measureable
(Group de Travail: bruit d’origine ferroviaire, 1988).

From the evidence reviewed in this section and in Section 5 below, it seems clear that at
daytime facade noise levels LAeq of less than about 60 to 65 dBA railway noise is
generally acceptable. For a level of 65 dBA about 25 to 30% of people are annoyed and
10 to 20% seriously annoyed. At a level of 70 dBA, 40 to 50% are at least annoyed and 15
to 30% seriously annoyed.

Section 5 will show that most countries are setting noise insulation limits at about 65 dBA
LAeq,24hr or LAeq,day. In France, experience has shown that provided houses are insulated at
noise levels of 65 dBA or a little less, then there is no general opposition to new railways
on the grounds of noise. The current opposition to the proposed TGV line in Provence
may, however, prove an exception.

Four studies (Rucker, 1975; Kastka and Buchta, 1977; Holzmann, 1982; and Finke et al,
1980) provide some evidence of acceptable levels of night-time noise from roads and
railways. 25% of people are very annoyed when the external LAeq,night due to road traffic is
54 dBA, and 50% when it is 65 dBA. (Night-time is 2200 to 0600 hours.) Valet (1987)
suggests that above an internal noise level LAeq,night of 40 dBA and LAmax of 50 to 55 dBA,
sleep can be disturbed by noise from railways. With an allowance of 22 dBA for the
insulation provided by a single-glazed room with the window closed, which is the
standard assumed in France for noise insulation purposes, this suggests external facade
noise limits at night of 62 dBA LAeq,night and 72 to 77 dBA LAmax.

Rice and Morgan (1982) suggest that to avoid sleep disturbance, the facade noise level at
night should not exceed 55 dBA LAeq and 75 dBA LAmax for road traffic, and 60 dBA LAeq
and 85 dBA LAmax for railways, with the additional limit of no more than 20 noise events
per night. It is interesting that the 55 dBA LAeq limit suggested for roads is very similar to
the 54 to 55 dBA that is likely to occur on average at night alongside roads with a noise
level LA10,1hr of 68 dBA, which is the current standard for insulation against noise from
road traffic (see also Section 5).
Table 4.4  Community Reactions to Railway Noise

<table>
<thead>
<tr>
<th>Country (Study)</th>
<th>Measure of community response used</th>
<th>Noise index</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK (Fields &amp; Walker, 1982b)</td>
<td>General annoyance</td>
<td>$L_{Aeq,24hr}$</td>
<td>Percentage very much annoyed: 10% at 63 dBA</td>
</tr>
<tr>
<td>France (Aubree, 1975)</td>
<td>General annoyance</td>
<td>$L_{Aeq,24hr}$</td>
<td>All residents disturbed: $\geq 76$ dBA</td>
</tr>
<tr>
<td>France (Vernet, 1987 and 1988)</td>
<td>Disturbance</td>
<td>$L_{Aeq,12hr}$ (0800 to 2000)</td>
<td>Percentage disturbed and very disturbed: $&lt; 20%$ at 60 dBA 50% at 73 dBA</td>
</tr>
<tr>
<td>Switzerland (Heinze et al, 1980)</td>
<td>General annoyance</td>
<td>$L_{Aeq, day}$</td>
<td>Increase in reaction: 53 dBA</td>
</tr>
<tr>
<td>Netherlands (Peeters et al, 1983)</td>
<td>General annoyance</td>
<td>$L_{Aeq,24hr}$</td>
<td>Increase in reaction: 50 dBA</td>
</tr>
<tr>
<td>Denmark (Andersen et al, 1983)</td>
<td>General annoyance</td>
<td>$L_{Aeq,24hr}$</td>
<td>Percentage strongly annoyed 9% at 60 dBA 20% at 65 dBA</td>
</tr>
<tr>
<td>Sweden (Sörensen &amp; Hammar, 1983)</td>
<td>General annoyance</td>
<td>$L_{Amax}$</td>
<td>Percentage very annoyed: 20% at 85 dBA</td>
</tr>
</tbody>
</table>

Source: Ashdown Environmental Ltd (1989)

4.6 EXPOSURE TO NOISE FROM RAILWAYS

Fields and Walker (1982a) estimated the number of houses in Great Britain exposed to various noise levels from railways. They estimated the number exposed to more than 60 dBA $L_{Aeq,24hr}$ was 178,474; to more than 65 dBA, 59,667; and to more than 70 dBA, 17,834. The corresponding length of railway routes open to traffic was 18,166 km. Thus the number of houses per km exposed to different noise levels from existing railways was about 9.8 per km exposed to more than 60 dBA $L_{Aeq,24hr}$ 3.3 to more than 65 dBA and 1.0 to more than 70 dBA.

These estimates can be used to make a very approximate estimate of the number of houses exposed to different noise levels from new railways. The necessary assumptions, which may well not be valid, are that the distribution of houses along a new line is, on average, the same as that along existing lines and that the noise characteristics of new lines will be the same as those of existing lines in 1979.

Mr. Parry (1990b) quotes an estimate of 50 dwellings exposed to 60 dBA or more $L_{Aeq,24hr}$ along a 60 km length of line on the International Rail Link, and only one dwelling exposed to 70 dBA. This estimate must be provisional as the design of the link is not finalised. If it is correct, then it demonstrates that by careful design, sometimes at considerable additional cost, it is possible to keep down the number of dwellings near a new railway line exposed to high noise levels. The fact that only four houses needed to be offered insulation against noise as a result of the East Coast Main Line diversion at Selby again demonstrates that exposure to noise from new railways can be kept to a low level by careful design, albeit sometimes at a substantial construction cost penalty.

4.7 COST IMPLICATIONS OF THE NOISE LIMIT FOR INSULATION

Insulation of properties against noise typically costs £1,500 to £2,000 per house. Using the estimates of numbers of houses given above, the cost of insulating houses against noise from new railways would on average be very small compared to the other costs of
building a new railway. There would certainly be some new lines where the cost of insulation would be much higher than the estimated average cost. But these estimates are so small that, even if they are low by a factor of ten, the cost of insulation should not influence the selection of a noise standard for new railway lines. Of course, insulation only protects people from noise when they are indoors with the windows closed. It is preferable to reduce railway noise at source, even if this costs more than insulation, since this reduces the effects of noise on people out of doors as well as indoors. In practice, the cost of the design measures needed to reduce noise near new railways is likely to be greater than the cost of insulating houses.

5. EXISTING NOISE STANDARDS FOR ROADS AND RAILWAYS

5.1 INTRODUCTION

Noise standards for road traffic and railways have been introduced by both central government and local authorities. These standards have generally been established for two separate conditions; where a new road or railway is planned which will inflict noise on existing noise-sensitive buildings, and where a road or railway already exists but where new building development is planned near the existing transport route. The existing standards are examined here, not to recommend a standard for new railway lines by comparison, but rather to see how the noise level that will be derived in Section 6 as equitably equivalent to the existing 68 dBA LA10,18hr for roads compares with those chosen elsewhere.

In the case of new development near existing roads or railways, standards are normally set by local authorities as part of planning policy and serve as a means of ensuring that the building developer takes appropriate measures to minimise the noise impact at a site. When the prescribed noise levels are exceeded then the developer may be required to improve the noise insulation or the design of the buildings or, for conditions where an acceptable noise environment cannot be achieved, the authority may refuse planning permission altogether.

This form of standard or recommendation is clearly influenced by local conditions, which may include the relative need for new development in a particular locality, the existence of major transport routes and the availability of building land. In some areas, therefore, it may be possible to set stringent noise standards without significantly affecting new development; in others, pressures to increase the housing stock combined with limitations on the available land may lead to planning consents given at higher noise levels. The relatively stringent standards that are imposed by some authorities also reflect the greater opportunity to design for low noise environments in a new development, in contrast to retro-fitting extra insulation to existing property. Consequently, although planning standards cannot be used, without qualification, as evidence for the determination of equitable noise insulation standards for existing property exposed to noise from new roads and railways, they do provide an additional and useful measure of the general level of acceptability of a particular transport noise source as judged by local planning authorities over the country as a whole.

5.2 NOISE STANDARDS FOR ROADS IN BRITAIN.

5.2.1 Noise Standards for new roads (The Noise Insulation Regulations)

Road traffic noise has been the subject of considerable legislative activity, particularly during the early seventies. The White Paper "Development and Compensation – Putting
People First" was published in October 1972 (Secretary of State for the Environment, 1972) and heralded the introduction of the Land Compensation Act 1973. It followed two major studies dealing with ways of preventing damage to the environment from essential public development and, for situations where full prevention was not practical, how to compensate for it.

In summary, the Act contained five major provisions relating to roads:

(i) A new right for owners and owner-occupiers of dwellings, owner-occupiers of farms, and owner-occupiers of other premises below a specified rateable value to claim monetary compensation for depreciation in the value of property due to the effects of traffic on a new or altered road, even though no land is taken from them for the actual construction;

(ii) A power for the Secretary of State to make regulations imposing a duty or conferring a power on the responsible authority to insulate buildings against noise caused by the construction or use of public works;

(iii) Powers for highway authorities to acquire land for mitigating the effects of highway construction or use on the surroundings — including buying out owner-occupiers of very seriously affected properties so that they could move elsewhere;

(iv) Powers for highway authorities to carry out works on land so acquired, or on other highway land, to mitigate the effects of a highway eg by noise barriers, tree planting;

(v) Powers for highway authorities to pay expenses of temporary re-accommodation of occupiers during particularly disturbing phases of construction work.

In 1971 the Secretary of State for the Environment announced (House of Commons, 1971) that, in the context of noise in the vicinity of urban motorways, the Noise Advisory Council had recommended that existing residential development should in no circumstances be subjected, as an act of conscious public policy, to more than 70 dBA on the L10 index unless some form of remedial or compensatory action was taken by the responsible authority. In the subsequent legislation (see below) the limit of 70 dBA L10 was reduced by 2 dBA to 68 dBA to allow a margin for errors in calculating or measuring the noise level near a new road.

As part of the new powers under the Land Compensation Act 1973, the Noise Insulation Regulations were introduced in England and Wales on 1 September 1973 and were later modified in November 1975. The current form of the Regulations includes an improved method of calculating noise and dates from December 1988 (House of Commons, 1988). When determining entitlement under the Regulations for noise insulation treatment, three conditions have to be tested, and all three satisfied:

(i) The relevant noise level* must not be less than 68 dBA on the L_{A10,18hr} index. (The L_{A10,18hr} dBA is the average of the 18 one hour values of L_{A10} taken between 0600 and 2400 hours on a normal working day.)

* The relevant noise level is defined as the highest estimated noise level for a normal weekday occurring over a 15 year period from the date of opening the road. The noise level is assessed at a reception point located one metre in front of the most exposed part of an external window or door of an eligible room.
(ii) The relevant noise level is at least one dBA more than the prevailing noise level, i.e., the total traffic noise level existing before the works to construct or improve the highway were begun.

(iii) The contribution to the increase in the relevant noise level from the new or altered highway must be at least one dBA.

The Noise Insulation Regulations define an insulation package to be offered to owners of dwellings that qualify for noise insulation.

The owner of a dwelling near a new road, who has not been offered noise insulation, may, during the first year after opening, challenge the calculated noise level from the road.

In addition, discretionary powers were granted to allow highway authorities to: insulate property in relation to noise generated during the construction of a road; allow insulation for altered highways; and to allow anticipation of the expected noise from a new road so that insulation could be provided before the road was constructed.

Discretionary powers were also provided to allow the insulation of property which would not normally meet the necessary noise criteria listed above but which forms part of a contiguous facade where other adjacent properties in the block of dwellings do qualify.

Motorway Service Areas, which are in some ways analogous to railway stations or sidings, are not subject to the Noise Insulation Regulations because they are not highways maintainable at public expense, but slip roads to and from Service Areas are subject to these Regulations. Motorway Service Areas are considered for Part I compensation purposes under the Land Compensation Act 1973.

Despite the duties and powers contained in the Land Compensation Act 1973, the first priority for the designers of new roads is to keep the external noise levels as low as can be practically achieved. The White Paper “Development and Compensation – Putting People First” (Secretary of State for the Environment, 1972) states “The [Urban Motorways] Committee also propose that so far as reasonably practicable the environment should be preserved by the selection of the line and the design of the road and by remedial works on land adjoining it and that compensatory measures should deal with the adverse effects which cannot be so avoided. The Government welcome this report and believe this to be the right general policy.”

Reducing external noise levels involves the vertical alignment of the road and the use of terrain, earth bunds and noise barriers to reduce noise. It also includes the horizontal routing of the road to keep it away from sensitive areas. The position in France is similar, where the Circular of 2 March 1983 states “It is essential that technical improvements should be used to ensure that the design of new infrastructure creates a better environment . . . . The search for solutions to noise nuisance should be by the initial design of the road, by adequate protective treatments and by controls on adjoining urban development” (Ministre de l’Environnement, 1983).

5.2.2. Noise standards for existing roads.

For conditions where a road already exists and new noise sensitive development is planned, noise standards can be applied by the local planning authorities. Current advice on the principles and specific criteria by which the Secretaries of State for the Environment and Wales are guided in planning decisions, and on which they advise local
planning authorities to base their own policies, is contained in the DOE Circular 10/73/Welsh Office Circular 16/73 “Planning and Noise” (Department of the Environment, 1973). It deals with the siting of new development expected to give rise to noise and the siting of houses, schools, etc which may suffer from noise with particular reference to noise from roads, aircraft and industry. Railway noise is not considered in the current Circular.

The advice contained within 10/73, when dealing with the acceptability of noise levels from roads, states that there should be a strong presumption against permitting residential development in areas which are expected to become subject to noise in excess of 70 dBA $L_{A10.18hr}$. Currently this simple division between what is considered to be acceptable and unacceptable for planning purposes is being reconsidered by the Department of the Environment. A three tier standard is being investigated, based on the following outline criteria:

(i) Standard 1; this would be the level below which noise need not be considered as a determining factor in the granting of planning permission.

(ii) Standard 2; at this level there should be a strong presumption against the granting of planning permission. However, where it is felt that planning permission should be given above this level, for example where there are no alternative quieter sites available, conditions should be imposed by the planning authority to ensure an adequate level of external noise insulation, and,

(iii) Standard 3; above this level planning permission should always be refused.

A decision on the relevant facade noise levels which would trigger the criteria listed above has not been made at the time of writing. The Report of the Noise Review Working Party of the Department of the Environment (1990) recommends a level of 55 dB $L_{Aeq}$ for Standard 1.

5.3 NOISE STANDARDS FOR RAILWAYS IN BRITAIN

5.3.1 Noise standards for new railways

The situation for railways differs markedly from that already discussed for roads. While the road network has been greatly enlarged and improved since the Noise Insulation Regulations were implemented in the early seventies and, as a result, a large number of houses have been insulated from road traffic noise, there has been relatively little development of the railway network over the same period. Even though the number of new lines opened is small, a few cases do exist where new railways have been opened in recent years and where noise insulation criteria have been implemented by the operators of the railway. Table 5.1 summarises the noise criteria that have been applied in these cases.

In addition to those listed, British Rail have given undertakings to insulate property adversely affected by noise from new railway links in Manchester (Windsor Chord) and in Stockport (Hazel Grove Chord) although in both cases no insulation was subsequently found to be necessary. In both these cases a noise limit was not prescribed.

During the passage of the Channel Tunnel Bill through Parliament, Eurotunnel gave an undertaking to provide noise insulation to affected properties near to the Channel Tunnel facilities in East Kent. The undertaking was in respect of the likely noise that would be
created by the facilities once construction was complete. However, Eurotunnel have adopted the policy that insulation of relevant properties would be carried out at an early stage so that the householders concerned would also benefit during the period of construction. Essentially, Eurotunnel promised to abide by the same principles for the insulation of property as apply in the case of new roads under the Noise Insulation Regulations, but with the modification that a level of 50 L<sub>Aeq</sub> measured between 2200 and 0700 hours would be applied as well as the usual trigger level of 68 dBA L<sub>A10.18hr</sub>. Eurotunnel agreed that if either level was exceeded then the property would qualify for noise insulation. This is the only standard that the Committee has found that relates to sidings and stations rather than to through running lines.

Table 5.1 Noise Insulation Criteria for New Railways in Britain

<table>
<thead>
<tr>
<th>Authority/Operator</th>
<th>Railway</th>
<th>Noise Insulation Criterion (facade level L&lt;sub&gt;Aeq&lt;/sub&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower Hamlets/DLR</td>
<td>Docklands Light Rail (Beckton Extension)</td>
<td>65 24 hour</td>
</tr>
<tr>
<td>South Tyneside/</td>
<td>Tyneside Metro Rapid Transit System</td>
<td>60 24 hour</td>
</tr>
<tr>
<td>T &amp; W FTE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selby DC/British Rail</td>
<td>East Coast Main Line Diversion</td>
<td>(1)</td>
</tr>
<tr>
<td>GLC/British Rail</td>
<td>Liverpool Street Re-development</td>
<td>(1)</td>
</tr>
</tbody>
</table>

(1) No limits given but insulation offered to adversely affected property.

In addition to the above instances, where noise criteria have been applied to new railways and where insulation of existing property has been installed and paid for by the operator, a number of authorities have made similar recommendations for the insulation of property following the opening of a new railway. Table 5.2 summarises the standards recommended by various authorities. These are not necessarily set on the same basis as the 68 dBA L<sub>A10.18hr</sub> standard for new roads.

It can be seen from Table 5.2 that of the five authorities listed, all have made recommendations that the basic insulation criteria for new railways should be set at a level of 65 L<sub>Aeq</sub> during the day and, with the exception of the GLC, all have specified more stringent criteria for the evening and night periods. In addition, Kent County Council and the Avon, Gloucester and Somerset Environmental Monitoring Committee have included a maximum noise level standard for train movements during the night. The L<sub>Amax</sub> is intended to provide additional control of noise generated at night where it is known that particularly noisy single events can lead to sleep disturbance (see also Section 3.7).

In the context of the Channel Tunnel link British Rail has agreed to insulate houses exposed to noise from new railways where the facade noise levels are at least 70 dBA L<sub>Aeq,24hr</sub> (British Railways Board, 1988). In addition to the construction of completely new lines, they have also undertaken to offer sound insulation for conditions where the criteria were met and where alterations to an existing railway involved the addition of a new line or the alteration in vertical level of existing lines. The Board have agreed to adopt the same approach as the discretionary powers given under the Noise Insulation Regulations relating to new roads and contiguous facades. British Rail have also stated their intention to make an offer of sound insulation prior to construction starting.
### Table 5.2: Local Authority Recommendations and Guidelines for Noise Insulation Standards for New Railway Lines

<table>
<thead>
<tr>
<th>Authority</th>
<th>Proposed Standard (facade level L_{A_{eq}} unless otherwise stated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent CC</td>
<td>65 0700 to 1900</td>
</tr>
<tr>
<td></td>
<td>60 1900 to 2300</td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
</tr>
<tr>
<td></td>
<td>80 L_{A_{max}} 2300 to 0700</td>
</tr>
<tr>
<td>GLC</td>
<td>65 24 Hour</td>
</tr>
<tr>
<td>Consortium of London Boroughs</td>
<td>65 0700 to 1900</td>
</tr>
<tr>
<td></td>
<td>60 1900 to 2300</td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
</tr>
<tr>
<td>Avon, Glos. and Somerset</td>
<td>65 0700 to 1900</td>
</tr>
<tr>
<td>Environmental Monitoring</td>
<td>60 1900 to 2300</td>
</tr>
<tr>
<td>Committee</td>
<td>55 2300 to 0700</td>
</tr>
<tr>
<td></td>
<td>73 L_{A_{max}} 2200 to 0700</td>
</tr>
<tr>
<td>Gateshead</td>
<td>65 0700 to 1900</td>
</tr>
<tr>
<td></td>
<td>60 1900 to 2300</td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
</tr>
</tbody>
</table>

5.3.2. Noise standards for existing railways.

As in the case of roads, noise standards are applied by planning authorities to control the development of potentially noise sensitive development near to existing railway lines. However, to date there has not been any formal guidance issued by central government on the setting of appropriate noise levels for new development and local authorities have instead either tended to develop their own guidelines suited to their particular locality, or have followed the general advice resulting from three published studies. These are: The Report of the Greater London Council Working Party (1976), “GLC guidelines for environmental noise and vibration”; the Report produced by the Warwickshire Environmental Protection Council in 1981; “Community response to railway noise” (1981) and the Report in 1983 by the Midland Joint Advisory Council for Clean Air and Noise Control, “Railway noise and planning” (1983).

The GLC guidelines recommended that new housing unavoidably exposed to noise levels from railways of over 65 L_{A_{eq,24hr}} should be provided with sound insulation. The Warwickshire EPC established a standard of 63 to 68 L_{A_{eq,24hr}} as the noise level above which housing developments alongside railway lines would normally be allowed. This recommendation has been reviewed recently by the Council and the current advice is that new development will not be permitted where the noise exceeds 58 L_{A_{eq,24hr}}. They further stipulate that L_{A_{max}} measured between 2200 and 0700 hours should not exceed 88 dBA. The Midland Joint Advisory Council considered that the L_{A_{eq,24hr}} did not adequately represent night-time noise disturbance and that day (0700 to 2200) hours and night (2200 to 0700) hours should be considered separately. Their recommendations are:

(i) For levels which do not exceed 55 during the day and 50 L_{A_{eq}} during the night no special precautions are needed.

(ii) The use of noise screens should be considered if the daytime L_{A_{eq}} exceeds 55 dBA or the night-time levels exceed 50 L_{A_{eq}}.

(iii) Where site noise levels cannot be reduced to the levels given in (ii) then improved sound insulation of property or changes to building design and orientation should be considered.
(iv) Where the site noise due to a railway exceeds a daytime $L_{A_{eq}}$ of 65 dBA or a night-time $L_{A_{eq}}$ of 60 no new noise sensitive development should be permitted.

Table 5.3 summarises the various planning standards that have been introduced and are currently operated by different planning authorities. The table differentiates between standards which allow development only if sound insulation is provided by the developer and standards which, if exceeded, effectively prevent the granting of planning permission. The list was compiled from evidence received by the Committee from local authorities and is not intended to be an exhaustive coverage of all authorities who have considered railway noise standards.

<table>
<thead>
<tr>
<th>Authority</th>
<th>Standard (facade $L_{A_{eq}}$ dBA unless otherwise stated)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent CC</td>
<td>65 0700 to 1900</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>60 1900 to 2300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80 $L_{A_{max}}$ 2300 to 0700</td>
<td></td>
</tr>
<tr>
<td>GLC (1976)</td>
<td>65 24 hr</td>
<td>1</td>
</tr>
<tr>
<td>London Scientific Services (1990)</td>
<td>65 0700 to 1900</td>
<td>1</td>
</tr>
<tr>
<td>(Supported by Consortium of London Boroughs)</td>
<td>60 1900 to 2300</td>
<td></td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
<td></td>
</tr>
<tr>
<td>Gateshead</td>
<td>65 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Selby</td>
<td>65 24 hr</td>
<td>1</td>
</tr>
<tr>
<td>Norwich</td>
<td>60 24 hr</td>
<td>1</td>
</tr>
<tr>
<td>Surrey</td>
<td>66 $L_{A_{max}}$ 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>S Cambridgeshire</td>
<td>63 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Darlington BC</td>
<td>63 24 hr</td>
<td>1</td>
</tr>
<tr>
<td>Rugby</td>
<td>58 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Oldham</td>
<td>63 $L_{Amax}$ 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Birmingham</td>
<td>65 24 hr</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>70 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Bolton</td>
<td>63 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Warwick</td>
<td>58 $L_{A_{max}}$ 2200 to 0700</td>
<td>2</td>
</tr>
<tr>
<td>Wigan</td>
<td>65 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Cherwell DC</td>
<td>60 24 hr</td>
<td>1</td>
</tr>
<tr>
<td>Blyth Valley</td>
<td>60 24 hr</td>
<td>2</td>
</tr>
<tr>
<td>Solihull</td>
<td>68 0700 to 2300</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>63 2300 to 0700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80 $L_{A_{max}}$ 24 hr</td>
<td></td>
</tr>
<tr>
<td></td>
<td>58 0700 to 2300</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>55 2300 to 0700</td>
<td></td>
</tr>
<tr>
<td>East Hants.</td>
<td>63 $L_{A_{max}}$ 24 hr</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>83 $L_{A_{max}}$</td>
<td></td>
</tr>
<tr>
<td>Belfast</td>
<td>60 24 hr</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>80 $L_{A_{max}}$ 24 hr</td>
<td></td>
</tr>
<tr>
<td>Glasgow</td>
<td>63 24 hr</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>53 1900 to 0700</td>
<td></td>
</tr>
<tr>
<td></td>
<td>73 $L_{A_{max}}$</td>
<td></td>
</tr>
<tr>
<td>Dudley</td>
<td>65 0700 to 2200</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>60 2200 to 0700</td>
<td></td>
</tr>
</tbody>
</table>

1. Insulate new houses built near existing railways.
2. Planning permission refused if level is exceeded.
Most of the authorities use a noise level of 63 to 66 dBA $L_{Aeq}$ as the standard either for 24 hours or for daytime. Some, such as Warwickshire, use an appreciably lower level. These cases may well reflect local issues other than the direct environmental effect of transport noise.

5.4 NOISE STANDARDS FOR RAILWAYS IN DIFFERENT COUNTRIES

5.4.1 Noise from new railways

Table 5.4 summarises the national noise standards and guidelines introduced in different countries for new railways. The table only includes noise standards which apply for residential development and differentiates between standards which trigger the offer of sound insulation and those which are used as design guidelines where the insulation of property is not mandatory.

In Denmark the Ministry of the Environment and the Danish State Railways have determined guidelines for the limitation of noise from new railways. The agreed approach is to try to achieve the noise limits specified by taking appropriate design actions and by making use of local topography and purpose built barriers to screen sensitive buildings from the noise. There are no specific provisions to provide acoustic insulation of property at the design goal levels. However, the Ministry of the Environment is providing funds towards the insulation of property affected by noise from existing railways and it is likely that a similar policy will be adopted for new railways in Denmark.

The establishment of noise standards for new railways is currently under discussion in Norway. The limit value which is likely to be chosen is listed in the table and is considered to represent an equivalent standard to the noise standard set for roads in Norway.

<table>
<thead>
<tr>
<th>Country</th>
<th>Standard (façade level $L_{Aeq}$ unless otherwise stated)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>63 $L_{Aeq}$</td>
<td>24 hour</td>
</tr>
<tr>
<td></td>
<td>88 $L_{Amax}$</td>
<td>24 hour</td>
</tr>
<tr>
<td>Norway</td>
<td>60 recommendation only</td>
<td>24 hour</td>
</tr>
<tr>
<td>France</td>
<td>65 to 70</td>
<td>0800 to 2000</td>
</tr>
<tr>
<td>Sweden</td>
<td>63</td>
<td>24 hour</td>
</tr>
<tr>
<td></td>
<td>30 (indoor, living room)</td>
<td>24 hour</td>
</tr>
<tr>
<td></td>
<td>50 $L_{Amax}$</td>
<td>2200 to 0600</td>
</tr>
<tr>
<td></td>
<td>(indoor, bedroom)</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>59</td>
<td>0600 to 2200</td>
</tr>
<tr>
<td></td>
<td>49</td>
<td>2200 to 0600</td>
</tr>
<tr>
<td>Netherlands</td>
<td>60</td>
<td>24 hour</td>
</tr>
<tr>
<td></td>
<td>60 $L_{Amax}$</td>
<td>0700 to 1900</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>1900 to 2300</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2300 to 1700</td>
</tr>
<tr>
<td>Switzerland</td>
<td>50 to 65</td>
<td>day</td>
</tr>
<tr>
<td></td>
<td>40 to 55</td>
<td>night</td>
</tr>
<tr>
<td>Japan</td>
<td>70 $L_{Amax}$</td>
<td>24 hour</td>
</tr>
</tbody>
</table>

1. Guidelines for new railways running through residential areas.
2. Insulation of residential property provided when the levels are exceeded.
3. The 60 dBA limits are to be reduced to 57 dBA from 1st January 2000.
In Sweden the noise standard for new railways is based initially upon a predicted free field noise level of 60 L_{Aeq} (facade level 63 L_{Aeq}). In addition, the internal (measured) noise levels are specified for both living rooms and bedrooms. In Sweden most houses have very high standards of thermal insulation with triple glazing fitted as standard to most modern dwellings, giving facade insulations of, typically, between 35 and 40 dBA. However, some older properties in Sweden have poorer insulation and the Swedish National Rail Administration will offer improved sound insulation to owners of property affected by noise when any of the standard conditions are exceeded.

In France there is no formal legislation for the insulation of houses from railway noise although a noise insulation policy regarding noise from new railways has been introduced. The Circular defining actions to be taken with regard to noise from roads is applied to railways. The quality and cost of the insulation offered depends upon the ambient level existing before the line was constructed and also recognises the contribution of existing facades of properties to the acoustic insulation of the building.

If the ambient noise level prior to constructing the new railway is below 65 L_{Aeq} then efforts are made to reduce the contribution from the railway to below 65 L_{Aeq} and, if this cannot be achieved, additional insulation is provided. The objective is to improve the insulation of affected facades so that the external noise level is effectively reduced to 65 L_{Aeq}. For this purpose the French authorities assume that all untreated facades offer a baseline insulation of 22 dBA and this is then added to the difference between the target facade noise level and the actual level generated by the railway to obtain the degree of facade insulation required. For example, if the facade noise level from the railway is estimated to be 70 dBA and the target level is 65 dBA, then the insulation package offered would attempt to achieve a facade insulation of (22 + 5)dBA. A similar policy is adopted for conditions where the pre-existing ambient noise level exceeds 70 L_{Aeq}. In this case, however, the target level for the new railway is increased to 70 L_{Aeq} or better.

Germany has recently introduced more stringent noise standards for both new and altered railways (Bundesminister für Verkehr, 1990). The current noise limits are given in the table and have to be achieved for all new railway development, initially by appropriate design of the railway and by making use of barriers and other forms of screening (Railway Gazette International, 1990). If, after all such measures have been taken, the noise levels are still higher than the criteria for either the day or night period, then additional insulation is installed to affected property. Less stringent limits are applied for regions of low population density and for industrial areas.

In the Netherlands fairly stringent noise design goals have been set for both new and existing railways. However, although new railways are required to be designed so that these standards are met as far as possible, it is recognised that, where the use of barriers and other forms of screening cannot achieve the design targets, then further insulation of residential property will be needed. The trigger levels for the offer of sound insulation are included in the table. The initial design goals set by the Dutch Authorities are: 60 L_{Aeq,24hr}, 60 L_{Aeq,0700 - 1900}, 55 L_{Aeq,1900 - 2300} and 50 L_{Aeq,2300 - 0700}. These design goals apply to both new railways and existing railways where new development is planned. The 60 dBA levels are to be reduced to 57 dBA in the year 2000.

In Japan, noise guidelines have been introduced for all main line railways including the high speed Shinkansen network. However, no general noise standards or guidelines have been introduced for 'light' railways.

Table 5.4 does not include information on North America or Canada since neither country has introduced any federal noise standards regulating railway operations. Noise control from railways in the US is limited to the implications to operators provided by the
environmental impact statement. For example, most new transit systems in the US have, as a result of the requirements of the impact statement, included some form of design criteria to control excessive wayside noise and older systems have been subject to noise controls for extensions and improvements.

The noise generated by trains in the US is subject to a range of controls as a result of design guidelines and performance criteria. The Federal Railroad Administration have established noise measurement standards and emission criteria to cover a wide range of mainline rail vehicles. In addition, most mainline and transit authorities have procurement specifications which limit both the interior and exterior noise produced by the vehicle. This form of noise control is seen as a means of encouraging patronage of the system.

5.4.2 Altered railways and existing railways

The insulation policy for existing railways in Denmark requires the owner of affected property to contribute a proportion of the cost according to the severity of the noise problem. The lowest level to trigger the offer of sound insulation is 65 $L_{A_{eq},24hr}$ where the owner would have to pay 50% of the cost of the insulation materials and installation. At a level of 70 $L_{A_{eq}}$ the contribution from the owner reduces to 25% and above 75 $L_{A_{eq}}$ the contribution is 10%. The cost to the State has been estimated to be in the region of £3 million per year for a ten year period.

The Ministries of Transport and Environmental Protection in Norway have agreed to provide funds to reduce the noise impact from existing railways. In view of the high cost of this exercise the noise limits have been set at the relatively high level of 73 $L_{A_{eq}}$. The actions taken when the level is exceeded are, primarily, to erect noise barriers, but the insulation of property is also allowed when these measures fail to achieve the target noise level.

The authorities in Sweden will offer improved insulation to buildings affected by alterations to existing railways. Such alterations include the addition of new tracks to existing routes and changes to the alignment of existing tracks. For these cases the noise criteria are less stringent and reflect the view taken in Sweden that existing tracks are less intrusive than new railways. The noise criteria adopted for altered railways in Sweden are: 73 $L_{A_{eq},24hr}$ (facade), 40 $L_{A_{eq},24hr}$ (living room) and 55 $L_{A_{max},2200 - 0600}$ (bedroom).

Sweden is also involved in an extensive programme to insulate all buildings affected by noise from unchanged existing railways. The criteria adopted for these cases are: 78 dBA $L_{A_{eq},24hr}$ (facade) and, for bedrooms, 45 $L_{A_{eq},24hr}$ and 60 $L_{A_{max},2200 - 0600}$. The total cost of this policy has been estimated to be in the region of £10 million.

In Germany the same noise criteria apply to altered railways, where the track alignment is changed or where extra tracks are added, as apply to new railways. In addition, the noise has also to increase as a result of the change. The increase needed is 3 dBA for the nighttime period and an increase of any magnitude for daytime.

In the Netherlands an altered railway, for the purpose of noise insulation, is one where either the noise level has increased by more than 2 dBA and the noise level at the noise sensitive building is more than 65 dBA $L_{A_{eq},24hr}$, or at least one of the following changes have occurred: the 24 hour flow of a category of rail traffic has increased by more than 45%, the speed has increased by more than 20%, the rails have been displaced sideways by more than two metres, or the rails have been displaced vertically by more than one metre. (The legislation expresses this by defining that a change of less than the amounts listed above does not constitute an alteration.)
5.5 NOISE STANDARDS FOR ROADS IN OTHER COUNTRIES

This section is included to determine how the noise levels in other countries at which insulation of houses is provided differ between noise from roads and from railways.

As mentioned above, in France there is no formal legislation on insulation of houses against noise from new railways. The Circular that applies to noise from new roads is, in practice, applied directly to new railways. The Ministry of Housing, Transport and Maritime Affairs has commented that (our translation):

"Some studies appeared to show that the nuisance experienced by those living alongside railways was less, for a given measured noise level, than by those living alongside highways. A difference of 5 dBA could be shown to be allowable. . . . . . . In the present state of knowledge it seems to be important to remain prudent." (ie to continue to insulate against railway noise at the same level as road noise).

In Norway it is accepted that railways have a ‘bonus’ over roads of approximately 5 dBA at noise levels above about 65 dBA, but not below. Sound insulation is provided for houses exposed to facade noise levels from road traffic of 60 $L_{Aeq,24h}$ or more. However, according to planning procedures, some properties may be insulated at lower levels in the range 55 to 60 $L_{Aeq,24h}$ although there is no formal legislation requiring insulation at these levels.

In the Netherlands the current noise limits for roads are 55 dBA $L_{Aeq}$ for 0700 to 1900 hours, 50 dBA for 1900 to 2300 and 45 dBA for 2300 to 0700; for railways, 60, 55 and 50 dBA respectively (Ministry of Housing, 1987). From the year 2000 the 60 dBA limit for noise from railways is being reduced to 57 dBA. In all cases the noise limits can be increased by not more than a defined amount by central government at the request of the appropriate local authority or of the railway operator.

In Germany the noise limits applicable for railways are currently around 5 dBA higher than road noise levels, although this does not apply to shunting noise from marshalling yards.

6 THE DERIVATION OF A NOISE STANDARD FOR INSULATING DWELLINGS NEAR NEW RAILWAYS

6.1 INTRODUCTION

Although there are many ways in which the noise effects produced by roads and railways could be measured and assessed, the Committee considers that probably the most revealing is to examine the degree of annoyance or, preferably, severe annoyance caused by noise from each form of transport. An assessment of equity could then be established when the noise from each type of transport causes the same annoyance as expressed by communities directly affected by the noise.

However, this cannot be taken as the sole criterion. It is important to consider also the disturbance caused to communication, to rest and relaxation, and to sleep when assessing the overall effects of noise from roads and railways. These important aspects of disturbance have also been measured as well as annoyance and are distinct from it. It may be argued that annoyance is a direct consequence of disturbance, and therefore the latter
need not be observed separately. Railways appear to be more disturbing to communication, particularly conversation indoors, while roads cause rather more disturbance to sleep and general nuisance at night, and rather more general annoyance during the day, at a given noise level.

Naturally, these different criteria are likely to indicate different noise levels for a new railway that cause the same levels of annoyance and disturbance as those caused by a noise level of 68 dBA $L_{A10,18r}$ from a new road. To achieve a single value for a noise standard it is necessary to form a judgement on the relative importance of general annoyance, disturbance to communication, disturbance to rest and relaxation, and disturbance to sleep.

The practices of several countries and British local authorities in protecting dwellings from transport noise emphasise that insulating buildings is a measure of last resort. Whenever possible, the noise should be reduced at source or the transport link should be designed to contain whatever noise is produced. This can be done by taking into account the vertical and horizontal alignment of the route to enable the surrounding land to shield wayside communities from noise, by the use of noise barriers, by design of the permanent way and by the design or selection of rolling stock. Only if these measures do not reduce wayside noise to an acceptable level should existing houses have insulation fitted.

### 6.2 GENERAL AND DAYTIME NOISE

After giving weight to the more technically reliable and comprehensive studies, and using where possible evidence from Britain, it appears that railways are somewhat less annoying than roads at the same level of noise. The differential is at the lower end of the range of 4 to 15 dBA $L_{Aeq}$ found by the excellent study by Fields and Walker (1978, 1982a). The difficulties of comparing results from different surveys prevent this differential being quantified precisely, but it probably lies in the range 3 to 5 dBA. There is evidence that railways cause less overall annoyance at night and, though the evidence is less strong, that they are more acceptable in urban areas than in rural areas. There is also some evidence that freight trains are more annoying than passenger trains, but again the evidence is not strong.

Although there have been fewer studies of disturbance than of annoyance, the studies that have been done agree reasonably well over the disturbance caused by the two forms of transport. Railways disturb daytime activities that involve communication more than do roads. The differentials against railways are estimated to lie in the range -2 to 5 dBA $L_{Aeq}$ outdoors and indoors with the windows open, so a best estimate of 2 or 3 dBA $L_{Aeq}$ is reasonable. The differential against rail indoors with windows shut is larger.

The derivation of a noise level for railways that is equitably equivalent to the 68 dBA $L_{A10,18r}$ for roads is as follows.

i) Because of the intermittent nature of railway noise, the best measure of noise from railways is the A-weighted equivalent noise level $L_{Aeq}$.

ii) Section 2.4 showed that for road traffic noise the level measured as $L_{Aeq,24hr}$ was 3.5 dBA less than that measured as $L_{A10,18r}$. Thus the noise standard for roads is, in terms of equivalent noise level, 64.5 dBA $L_{Aeq,24hr}$ (Tenths of decibels are not detectable as differences in noise level, but for clarity of arithmetic they are retained in the intermediate working stages of this section and Section 6.3. The final results are rounded to whole decibels.)
iii) With the average diurnal pattern of road traffic, the 24 hour $L_{Aeq}$ of 64.5 dBA is made up of a daytime 18 hour noise level of 65.6 dBA $L_{Aeq}$ and a six hour night-time $L_{Aeq}$ of 55.6 dBA.

iv) During the day, railways are probably less annoying than roads, but the scientific evidence is not precise (the most likely differential is in the range 3 to 5 dBA). Some trains are more annoying than others and reduce the favourable differential. Similarly, the differential in favour of rail is probably less in small towns and rural areas than in large urban areas, though not all studies show this effect. There is limited but consistent evidence that railways cause more disturbance to communications than do roads, with the differential against railways being 2 to 3 dBA. There is also limited evidence that railways cause slightly more disturbance to outdoor rest and leisure, and slightly less to indoor leisure activities.

v) The Committee believes that the fairest way to equate road and rail noise is to set a standard that allows a daytime noise level for railways of 67.6 dBA $L_{Aeq}$ which is 2 dBA above the daytime 18 hour noise level of 65.6 dBA $L_{Aeq}$ for roads. This differential attempts to balance the lower annoyance and greater disturbance caused by railway noise during the day. At this level people will experience more interference with communication than they would from roads, but less general annoyance.

vi) Because rail traffic is ultimately scheduled by the railway operator and road traffic is not scheduled by the road constructor, the Committee consider it important that the standard for railway noise covers the full 24 hours. A noise level of 67.6 dBA $L_{Aeq}$ over 18 hours contains the same acoustic energy as one of 66.3 dBA $L_{Aeq}$ over 24 hours, and the one measure is therefore equivalent to the other. The Committee therefore recommends a standard for railway noise of 66 dBA $L_{Aeq,24hr}$ rounding to the nearest decibel.

The Committee considers that it is better to recommend a simple standard for daytime noise, as outlined above, rather than propose a complex standard with the noise level at which insulation is provided varying between rural and urban areas and between lines used for freight traffic only, passenger traffic only, mixed traffic and high speed trains. Similarly, it considers that the same standard should apply to light railways as heavy railways. Measurements of noise and annoyance near the Docklands Light Railway suggest that the effects of light and heavy railways are similar. The evidence on the effects of railway noise is not good enough to justify such complexity, and a complex standard could pose operational problems for the railway operator.

6.3 NIGHT-TIME NOISE

Measurements of noise from roads in Britain and Germany both show that the naturally occurring pattern of road traffic leads to night-time noise levels that are on average 10 dBA less than daytime levels. The British measurements defined day as 0600 to 2400 and night as 0000 to 0600, to match the 18 hour period over which road traffic noise is measured or calculated for testing eligibility for noise insulation. Some railway lines will show similar diurnal noise patterns but others, particularly those carrying freight, may not.

Studies of the disturbance to sleep caused by railways show clearly that railways are less disturbing than roads and that the differential in favour of railways is at least 5 dBA. Therefore the night-time noise level from a new railway can equitably be 5 dBA more than that from a new road, for equal disturbance to sleep. A road that causes the limiting
noise level of 68 dBA $L_{A_{10,18hr}}$ would be expected to produce a night-time noise level of 55.6 dBA $L_{A_{eq,6hr}}$. Thus the limit for night-time noise for a railway should be 61 dBA $L_{A_{eq,6hr}}$, which is 5.4 dBA above the night-time noise level from a road that is just noisy enough to require insulation to be offered. At this noise level people living near new railways will experience no more sleep disturbance than those living near new roads.

For equity the period over which the lower-night time noise level applies should be the six hour period from midnight to 0600 hours that is not included in the measurement period for noise from roads. However, this six hour period is shorter than the period generally recognised as ‘night’ on behavioural grounds.

In the context of noise from airports, night is taken to be 2300 to 0700 hours. There is evidence of the need to avoid loud noises between 2200 hours and midnight, when adults are getting to sleep and are most prone to sleep disturbance. (A similar argument would apply to earlier in the evening when children are getting to sleep.) There would appear to be good grounds for departing from the strict criterion of equity in respect of the period defined as night-time, and for applying the night-time noise limit of 61 dBA $L_{A_{eq}}$ over the period of at least 2300 to 0700 hours.

6.4 POSSIBLE LIMITS TO THE MAXIMUM NOISE LEVEL

Another issue is whether the duty to insulate dwellings near new railway lines should be triggered by the maximum noise made by individual trains on the line. There is no equivalent condition in the Noise Insulation Regulations, and however desirable such a limit would be at night, it could not equitably be required. But the maximum noise a road vehicle can produce is limited by EC Directives (implemented in this country through the Road Vehicles (Construction and Use) Regulations).* There is no such requirement for rail vehicles, although there has been an unsuccessful attempt to produce an EC Directive on this topic. A trackside maximum noise level for railways could arguably be regarded as taking the place of the maximum pass-by noise limit for individual road vehicles. The Noise Review Working Party (Department of the Environment, 1990) recommends that consideration be given to the introduction for railways of an equivalent to the Road Vehicles (Construction and Use) Regulations to control the noise from locomotives and rolling stock.

The Committee considered whether there might be scope for regulation of the maximum pass-by noise from trains, to match the existing regulation of noise from road vehicles. Provided the railway operators continue to reduce pass-by noise from new trains, then type approval regulations are probably not needed. They could be counter-productive if, because of the inevitable compromises required over possible European legislation, a regulation was set that was less stringent than the operators currently demand in their equipment specifications.

From the point of view of acceptability, rather than equity, there is a good case for including a night-time maximum noise limit in the standard for insulating houses against noise from new railways. This is because night-time rail traffic could well consist of a few rather noisy trains which produce a low equivalent noise level averaged over the whole night, but maximum noise levels that are enough to disturb sleep several times a night.

* Road vehicle noise regulations define the maximum allowable noise a vehicle can produce under a specified condition which represents a full throttle acceleration at low speed. This noise level is about the same as that produced at high speed, and that would be measured beside a high speed road.
For example, high speed trains such as the TGV produce maximum noise levels of 90 to 95 dBA $L_{A_{max}}$ at a distance of 25 metres from the track. This is high enough to cause sleep disturbance.

In the context of a maximum noise limit, it is relevant to note that in the British Rail document "Rail link project – Environmental planning and appraisal procedures (Issue 2)" (British Rail, 1990) the following statement is made: "A further aim is to ensure that the maximum passing noise (peak noise) of the Rail Link train movements outside residential property does not exceed 85 dBA, and that the 24 hour $L_{A_{eq}}$ measurement of noise outside residential property does not exceed 70 dBA. If these levels are not achieved in the design, consideration is to be given to the provision of appropriate mitigation measures."

The Committee, while recognising that a maximum noise level cannot be required on the basis of equity with roads, except as an alternative to a type approval noise limit for road vehicle pass-by noise, urges the Secretary of State to note British Rail's aim of a maximum noise limit and to consider including it in the standard for noise from new railways.

6.5 DEFINITION OF NEW RAILWAY LINES

The Land Compensation Act 1973 and the Noise Insulation Regulations 1975 define clearly what is meant by a new road. Briefly, a new road is defined where major construction has occurred, such as building a road where there was none before or expanding a single carriageway road to a dual carriageway one. There is discretionary power to include as a new road one widened by one lane. The Department of Transport has decided to exercise this power. Maintenance, minor widening, junction improvements, installing signs or lighting does not create a new road under the terms of the Regulations. Similarly, insulation is not provided where traffic noise increases as a result of a traffic management scheme, of the road becoming a feeder to a new major road, or of natural traffic growth.

The corresponding definitions of a new railway line are not so easy to establish. There are clear cases such as lines across green-field sites and the re-opening of lines which had been abandoned before adjoining homes were built. But there are cases such as electrification which have no road analogy. Similarly, the traffic on a railway can be intensified by minor construction such as passing loops and re-signalling or traffic can be re-scheduled into previously lightly loaded times. This can lead to situations where intensification could not have been foreseen and is so great that it completely changes the nature of the line. The Noise Review Working Party (Department of the Environment, 1990) recommends that if houses are to be insulated against noise from new railways, then consideration should be given to insulating them against noise from railways that had been subject to intensification of use that could not have been reasonably foreseen.

Virtually all the standards for road and railway noise relate to highways and running lines. Motorway Service Areas and railway sidings are eligible for possible Part I compensation under the Land Compensation Act 1973, and slip roads to and from Service Areas under the Noise Insulation Regulations. The Committee consider that it is for the Secretary of State for Transport to specify whether regulations relating to railway noise should apply to sidings, etc, as well as to running lines.

The Netherlands has a set of quantified criteria for changes to traffic flow, speed or track position that define an altered railway. Several other countries prescribe a defined
increase in noise level, often with a second criterion for the absolute noise level, as defining an alteration to a railway line that triggers a duty to insulate affected buildings.

Many people who contributed evidence to the Committee believed that noise insulation should be provided for houses near railways on which traffic has increased abnormally. Although the definition of a new railway for the purposes of future noise insulation regulations for railways is not for consideration by this Committee, it is felt that the Secretary of State for Transport should give appropriate weight to the differences between railways and roads when establishing this definition.

6.6 BUILDINGS TO BE INCLUDED

Because noise from railways interferes more with communications than does noise from roads, it seems likely that it will cause more disturbance than road noise in non-domestic buildings where communication is important, though there is little hard evidence. Thus, even though non-domestic buildings are not covered by the Noise Insulation Regulations, the greater disturbance to daytime activities by railway noise suggests that consideration should be given to insulating some classes of non-domestic noise-sensitive buildings against noise from railways. If some classes of buildings other than dwellings become eligible for insulation against noise from new roads, as is being recommended by the Noise Review Working Party (Department of the Environment, 1990), then the same classes of building should be eligible for insulation against noise from new railways.

6.7 NOISE FROM RAILWAYS UNDER THE GROUND

The Committee did not initially consider that noise from railways under the ground fell within their remit and did not ask for evidence on this topic. London Underground Ltd have told the Committee that this has been a frequent problem with new underground lines. Since this type of noise propagates through the ground into the foundations of a house it cannot be reduced by modifications to the house such as noise insulation. It must be reduced at source, and the technology to do this exists. It is sometimes expensive to apply, though less so if done during construction.

It is not possible to predict accurately the noise level caused by a railway under the ground, although an approximate estimate can be made when the geological characteristics of the area are known. It is possible to predict more accurately, though not precisely, the effects of technical measures to reduce noise, once the noise level in the dwelling from the railway as built is known. Since insulation is not an appropriate countermeasure against noise from railways under the ground, the Committee has decided not to consider it.

7 THE PREDICTION OF NOISE FROM RAILWAYS

Whatever standard is adopted for the noise level at which houses are insulated against noise from new railways, it will be necessary to establish a method of assessing which houses are eligible. For road traffic, noise entitlement is normally established using a prediction method designed specifically for this purpose. The method is called "The Calculation of Road Traffic Noise" (CRTN), and the use of this method is specified in The Noise Insulation Regulations for roads. This calculates the highest noise level expected at the facade of the house concerned during the first 15 years after the opening of the road, taking account of the predicted traffic volume, the composition of heavy vehicles and the speed of the traffic during that time. This calculation is usually performed by those designing the road, using the method and traffic forecasts approved.
by the Department of Transport. Where predictions are considered to be unreliable because of complexities of the scheme, recourse to measurement is permitted and the method also includes advice on measurement practice and instructions on how the measurements should be applied.

A number of factors make it necessary to use a slightly different procedure for the calculation of noise near new railways. The first of these is that to predict the noise near a railway, the noise at source of the various trains using the line must be known. In the case of a road, only the average noise from heavy and light vehicles needs to be assumed as the noise source. The second is that the forecast of traffic on a railway line will be specific to the line concerned, whereas for a road the national traffic forecast can be used, modified by specific local factors. The rail traffic forecast will be made by the operator and the actual development of traffic on the line will ultimately be under the control of the operator, though in practice decisions on traffic will be made in response to commercial considerations. The noise of the trains using the line could be that of existing stock or could be that required in the specification of new stock for the line. In either case the calculation will be performed by the operator. Because the noise from a railway can increase significantly as the track wears, the condition corresponding to the worst case over 15 years for roads should combine the noisiest traffic and the worst condition of the track before regrinding to remove corrugations on the rails.

To achieve an equitable situation between roads and railways the Secretary of State for Transport will need to approve the calculation method to be used for rail and also the traffic forecasts for each scheme. The Committee suggests that an expert working group, including among others representatives from British Rail, TRRL and the relevant directorates of DTp, could be set up to advise the Secretary of State on the development of a suitable method for calculating noise from new railways, including ways of approving the forecast of traffic on the line and the likely day/night distribution of that traffic.

8 CONCLUSIONS FROM THE EVIDENCE

There are considerable differences both in the character of the noise generated by roads and railways and in the way the two forms of transport are operated. These differences affect the way in which the noise needs to be measured and assessed, and the degree of annoyance and disturbance caused. As a result, it would not be equitable to apply to new railways the existing standard for insulating houses against noise from new roads, as set down in the Noise Insulation Regulations 1975 and 1988. Many aspects, such as insulation against construction noise and the right to challenge the calculated noise level, apply directly, but many others need to be considered and modified to fairly equate conditions near new roads and new railways (Sections 2.2, 4.2, 4.3 and 5.2.1).

Noise from railways should be assessed using the equivalent noise level scale, $L_{Aeq}$ (Section 4.1.2).

No single noise level from railways is the equitable equivalent of the 68 dBA $L_{A10}$ from roads, above which houses are insulated against noise. During the day and at noise levels of 65 to 70 dBA $L_{Aeq,24hr}$, railway noise is probably less annoying than road traffic noise, with a differential of 3 to 5 dBA in favour of rail. There are quite substantial differences in the studies reviewed. The relative annoyance from road and rail noise does seem to vary with the type of train; one study found that diesel and third rail electric lines are more annoying than overhead powered electric. It may also vary with the type of area through which the line runs; the differential between road and rail is probably less in
small towns and rural areas than in large urban areas, though not all studies agree on this (Sections 4.3.2 and 4.3.3).

Noise from railways causes more disturbance to communication than does noise from roads. The differential in noise level against rail for equal disturbance out of doors and in rooms with open windows is probably 2 to 3 dBA. The differential for disturbance to communication in rooms with closed windows was found to be substantially larger in one study (Section 4.2).

The Committee considers that, given the findings of the two preceding paragraphs, the daytime noise level near new railways that is equitably equivalent to 68 dBA $L_{A10,18hr}$ near new roads is 66 dBA $L_{Aeq,24hr}$. This 24 hour noise level can be achieved by railways that emit higher noise levels for only part of the day, such as 67.3 dBA for 18 hours, 69 dBA for 12 hours or 72 dBA for six hours. At a noise level of 66 dBA $L_{Aeq,24hr}$ people near new railways will experience more disturbance to communication (talking, teaching, using the telephone or listening to radio) and less general annoyance than people at a noise level of 68 dBA $L_{A10,18hr}$ near new roads (Section 6.2).

Noise from railways causes less disturbance to sleep than does noise from roads. The noise differential in favour of rail for equal sleep disturbance is at least 5 dBA. Studies have tentatively suggested that to avoid sleep disturbance the facade noise level from railways should be no more than 60 dBA $L_{Aeq}$ and the maximum noise level should be no more than 85 dBA $L_{Amax}$ with the additional proviso that there should not be more than 20 'noise events' per night (Sections 3.7 and 4.2).

Although most studies of rail noise and many of road noise find that both day and night annoyance are predicted by $L_{Aeq,24hr}$, this is at least partly because of the diurnal traffic pattern on virtually all roads and on many railway lines. The noise from roads during the six hours from midnight to 0600 is on average 10 dBA less than during the remaining 18 hours. To ensure equitable treatment of annoyance and disturbance at night from railways and roads it is necessary to specify a night-time noise limit for railways. This is because the scheduling of rail traffic is ultimately under the control of the railway operator, albeit in response to passenger demand and commercial pressures, and a diurnal traffic pattern that gives substantial reductions in noise levels at night cannot be assumed. The Committee considers that, in addition to the 24 hour noise limit, for equity there should be a night-time noise limit of 61 dBA $L_{Aeq,6hr}$ for new railways for the six hours of midnight to 0600. For compatibility with the definition of night used in the context of airport noise (where the intermittent noise provides a closer comparison with rail noise than does noise from road traffic), and for acceptability to trackside residents, the Committee considers that the requirement for equity should be relaxed and that night should be defined as 2300 to 0700 hours (Sections 2.2 and 6.3).

There is a considerable uniformity in the noise level set as a limit for insulating houses near new railways by those countries that have set such limits, though the basis on which these limits were selected is not always known. The same level has been selected by most British local authorities that have set limits to control development near existing railways. That level is about 65 dB, either $L_{Aeq,24hr}$ or $L_{Aeq,day}$ where 'day' would typically cover the period 0700 to 2200 hours (Sections 5.3 and 5.4).

Several European countries have set noise limits for railways 5 dBA louder than the limits for roads, but France appears to use the same noise limit for roads and railways (Section 5.5). Although the Committee's terms of reference did not include consideration of the acceptability to trackside residents of the noise level that was equivalent with the 68 dBA $L_{A10,18hr}$ for roads, there is considerable evidence that the level of 66 dBA $L_{Aeq,24hr}$ recommended for railways is the highest that has been found to be acceptable without
insulation. The night-time limit of 61 dBA $L_{A_{eq,night}}$ is at or marginally above the level that has been found to be acceptable, but the limit is not known precisely (Section 4.5).

In determining entitlement for insulation it will be necessary to develop a method of prediction and measurement for railway noise that is similar to that used for road traffic. However, there are differences in the calculation of noise from roads and railways and these differences would need to be taken into account in formulating the procedures adopted. The calculation method used and the traffic forecasts for each scheme should be approved by the Secretary of State for Transport as is the case for new roads (Section 7).

The Noise Insulation Regulations include a number of technical acoustic requirements, rights of residents to challenge calculated noise levels, discretionary powers, and a specification of an insulation package relating to noise from new roads. Consideration should be given to including such provisions in any regulations relating to noise from new railways (Section 5.2.1).

Insulation of noise-sensitive buildings should be regarded as a second-best approach to reducing the adverse effects of noise from new railways, as it only protects people when they are indoors with the windows closed. A preferable approach is to reduce the noise level at source as far as is reasonably practical, even if this costs more than insulating nearby houses. Noise insulation should then be provided for those houses where the external noise levels cannot be reduced below some defined level (Sections 4.6 and 5.2.1).

The cost of insulating dwellings against noise from new railways is small compared to the other costs of building a new line and, probably, to the cost of reducing noise near railways by design. The cost of insulating dwellings is such a small fraction of the total cost of a new railway that it should not be allowed to influence the selection of a noise limit for eligibility for insulation (Section 4.6).

Because noise from railways interferes with communication more than does noise from roads, activities that involve communication will be more affected by noise from railways than by noise from roads. Non-domestic buildings in which the principal activities depend on communication will be similarly affected. Even though such buildings are not at present insulated under the Noise Insulation Regulations, consideration should be given to whether any non-domestic buildings should be insulated against railway noise (Sections 4.2 and 6.6).

What constitutes a new railway line for the purposes of the regulations will need to be considered. Many people who contributed evidence to the Committee believe that in addition to completely new railways, houses should also be insulated against significant increases in railway noise that result from intensification of use of an existing railway that could not reasonably have been foreseen (Sections 5.4.2 and 6.5).

Many railway operators set their own limits for the pass-by noise from locomotives and rolling stock, and these do not seem to cause excessive technical or financial problems. It is not considered practical to set a limit for the maximum noise, $L_{A_{max}}$ from a single train on a new line because of difficulties of definition and measurement in the presence of other noise sources, although some countries and authorities do set such a limit. It would be practicable to set a maximum pass-by noise level for a train at a given speed on a defined standard of track, to be assessed by calculation once the noise of the train under standard conditions is known (Sections 2.3.2 and 4.6).
Provided the railway operators continue to reduce pass-by noise from new trains, then type approval regulations to limit the maximum pass-by noise from locomotives and rolling stock, as is done for road vehicles and aircraft, are probably not needed. Indeed, legislating for less stringent noise levels than are currently being achieved by British Rail could be counter-productive as it might reduce the incentive for the railway operators to continue to reduce the external noise from new trains (Section 6.4).

9 RECOMMENDATIONS

These recommendations are intended to apply to all railways, including Light Rapid Transit systems, except for railways running under the ground and Light Rapid Transit systems running on roads.

9.1 GENERAL APPROACH

1. Those responsible for new railway lines should take all reasonably practical steps to reduce noise in the corridor along the line. The steps considered should include quietening the locomotives, rolling stock and permanent way at source, track maintenance, lowering the level of the track to shield it by the surrounding terrain and installing noise barriers. Insulation of dwellings against noise should be considered when the noise level near the line cannot be reduced to a defined level by other means.

9.2 A STANDARD FOR NEW RAILWAYS THAT IS EQUITABLY EQUIVALENT TO THAT FOR NEW ROADS

2. The noise level near the track should be determined using the A-weighted scale and expressed in terms of the equivalent noise level $L_{A_{eq}}$ averaged over a specified time period.

3. Those responsible for a new railway should have a duty to offer to insulate against noise those rooms of dwellings near the new railway line that are exposed to a facade noise level from the railway of at least 66 dBA $L_{A_{eq,24hr}}$. This level should be measured or predicted at a point located one metre in front of the most exposed part of any relevant window or door of a dwelling. This recommendation should only apply to those categories of room defined in the Noise Insulation Regulations for insulation against noise from new roads.

4. Those responsible for a new railway line should also have a duty to offer to insulate against noise those rooms of dwellings near the new railway line that are exposed to a night-time facade noise level from the railway of at least 61 dBA $L_{A_{eq,night}}$. Equity with roads would require that the period of night should be the six hours from midnight to 0600. However, for compatibility with the definition of night used in the context of airport noise (where the intermittent noise provides a closer comparison with rail noise than does noise from road traffic), and for acceptability to trackside residents, the Committee recommends that the requirement for equity be relaxed and that night be defined as 2300 to 0700 hours.

5. The noise levels should be those expected under the noisiest operating conditions anticipated in the 15 years after the opening of the new line.
6. The duty to offer insulation against noise should only apply if the railway noise has increased the noise level by at least 1 dBA and the new railway contributes at least 1 dBA to the total railway noise level after it becomes operational.

7. Those responsible for a new railway line should, where necessary, be granted discretionary powers to insulate buildings which form contiguous facades on the same basis as is used for roads.

8. Those responsible for a new railway line should, where necessary, have discretionary powers to insulate buildings exposed to excessive noise during construction of the new railway line, on the same basis as is used for construction noise of new roads.

9. The Secretary of State should specify an acceptable method of calculating the likely future noise level from a new railway line and should approve the forecast of traffic used to calculate the noise level. The Committee recommends that an expert working group be set up to advise the Secretary of State on the development of a suitable method of calculating noise from new railways, including ways of approving the forecast of traffic on the line and of the likely day/night distribution of the traffic.

10. The Secretary of State should specify the noise insulation package that should be offered.

11. The owner of a dwelling near a new railway should have the right, during the first year after the opening of the railway, to challenge the calculated noise level from the railway.

12. The Secretary of State should specify what degree of construction, change in capacity, change in use or change in noise level should be considered a new railway line.

13. The Secretary of State should specify whether regulations relating to railway noise should apply to sidings, stations and other similar areas as well as to running lines.

14. If at some future date the noise level for the insulation of houses near new roads is changed, the noise level at which dwellings are insulated against noise from new railways should be changed to maintain the equity between the two forms of transport. Similarly, if the Noise Insulation Regulations are extended to cover buildings other than dwellings, any regulations relating to noise from railways should be similarly extended.

9.3 OTHER MATTERS

15. The Secretary of State should note British Rail's offer to insulate against noise dwellings near the proposed International Rail Link exposed to a maximum noise level when a train passes of more than 85 dBA $L_{max}$, and should consider including this condition in the standard for insulating dwellings against noise from new railways, even though it is not required for equity with noise from new roads.

16. The Secretary of State should give consideration to the desirability of requiring those responsible for a new railway line to insulate some classes of non-domestic but noise-sensitive buildings.
17. When a new railway line is opened the reactions of the population in the adjoining corridor should be studied to try to reduce the present uncertainty over people's response to noise from new railway lines.

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APPENDIX 1

LIST OF CONTRIBUTORS OF EVIDENCE TO THE COMMITTEE

Local Authority Associations
Association of County Councils
Association of District Councils
Association of Metropolitan Authorities
London Boroughs Association

Local Authorities
Ashford Borough Council
Avon, Glos. and Somerset Environmental Monitoring Committee
Belfast City Council
Birmingham City Council
Blythe Valley Northumberland
Bolsover District Council
Castle Morpeth Borough Council
Cherwell District Council
City of London
Dacorum Borough Council
Darlington Borough Council
Dartford Borough Council
Dudley Metropolitan Borough Council
East Hampshire District Council
Gateshead Metropolitan Borough Council
Glasgow City District Council
Gloucestershire County Council
Gravesham Borough Council
Kensington Parish Council
Kent County Council
Lancashire County Council
London Borough of Barnet
London Borough of Bexley
London Borough of Bromley
London Borough of Hillingdon
London Borough of Lambeth
London Borough of Richmond-upon-Thames
London Borough of Tower Hamlets
Marden Parish Council
Merseyside Information Service
Metropolitan Borough of Stockport
Midland Joint Advisory Council for Clean Air and Noise Control
New Forest District Council
Newbury District Council
Newport Borough Council
Norwich City Council
Oldham Metropolitan Borough Council
Rochester-upon-Medway City Council
Rugby Borough Council
Selby District Council
Solihull Metropolitan Borough Council
Somerset County Council
South Norfolk District Council
South Cambridgeshire District Council
South Oxfordshire District Council
Surrey County Council
Tonbridge and Malling Borough Council
Warwick District Council
Warwickshire Environmental Protection Council
West Yorks. Highways Engng. and Technical Services Joint Cttee.
Woodspring District Council

Consultants, operators and professional bodies
Arup Acoustics
Ashdown Environmental Ltd
British Standards Institute
British Coal Corporation
British Railways Board
British Rail Research
Building Research Establishment
Council for the Protection of Rural England
Philip Dunbavin Acoustics Ltd
English Heritage
Eurotunnel
Green Wall Sound Barriers Ltd
Institute of Environmental Engineering, South Bank Polytechnic
J M P Consultants Ltd
Land Conservation Associates
London Underground Ltd
London Transport
London Scientific Services
Martec Environmental Engineering
Mr R Taylor (consultant in acoustics and noise control)
National Society for Clean Air and Environmental Protection
Professor R Bottle
Professor P Grootenhuis
Redland Plaster Board Ltd
Royal National Institute for the Deaf
The Institution of Environmental Health Officers
The Institute of Sound and Vibration Research
The Motor Industry Research Association
Travers Morgan Ltd
Tyne and Wear Passenger Transport Executive Group

Individuals
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Corson T M
Davis L M
Douglas P
Edwards A
Fielding A
Godfrey N M
Hardman J D
Henderson J A B
Herbert N G
Jones F G
Knight R
Lawrance J K
Lee P D
Neaves D C
Patterson K A C
Pitt J
Strategic and Environmental Rail Links Lobby (SERL)
Swanley Concern About Rail Freight (SCARF)
Temple D J
The Neil Wates Charitable Trust
Tribe C D
Weeks R
Williams G

Overseas
Banverket, Sweden
P J A Van Buchem, The Netherlands
K C Halvorsen, Norway
Herrn Dipl.-Ing. B. Hauck, West Germany
Institut National de Recherche sur les Transports et Leur Sécurité, France
R Lutz, Sweden
Ministère de L'Équipment, du Logement, des Transports de la Mer, France
K Murata, Japan
Odegaard Danneskiold-Samsoe ApS, Denmark
Organisation for Economic Co-operation and Development
Road and Traffic Research Institute, Sweden
Jan Söderstrom, Vagverket, Sweden
State Railways, Sweden
On 27 May 1992 the latest DT response to the Bachled Committee Tel: 071 276 6855 Mr. Nick De la RT, Railway Noise Division.
Draft issue of code procedure to be issued this year for comments.

NOISE STANDARD FOR NEW RAILWAY LINES

The Government's conclusions on the report of the Committee considering a noise insulation standard for new railway lines were announced today by Roger Freeman, Minister of State for Transport.

The announcement was made in Answer to a Parliamentary Question from John Bowis MP (Battersea), in which Mr Freeman said:

"We accept the Committee's view that those responsible for new railway lines should take all reasonably practical steps to reduce noise in the corridor along the line, provided that they are cost effective.

"We accept that there should be a nighttime noise insulation standard for noise from new railways as well as a daytime standard.

"We accept in principle that the detailed operation of the noise insulation standards for new railways should follow as closely as possible the system already provided in the Noise Insulation Regulations 1973 (as amended) in the case of new roads."

The Government proposes that the insulation standard should be 68 dBA_{L_{eq}} 18 hr for day and 63 dBA_{L_{eq}} 6 hr for night, on the basis that, in line with the existing noise insulation standard for new roads, daytime is defined as the 18 hours from 0600 to midnight. 68 dBA_{L_{eq}} 18 hr is a straight conversion from the 24 hour level recommended by the Committee.
Re: Date: - Make and a resound as available today
was from Flexer and Wether in 1970 - 80's to here
- WHO 1980 guidelines were available
In the case of the nighttime standard, both British Rail and the Transport and Road Research Laboratory have recently carried out analyses of more sets of road noise data than were available to the Committee. The decision that the nighttime standard noise for railways should be $63 \text{ dBA}_{L_{\text{Aeq}} 6 \text{ hr}}$ reflects the outcome of those later analyses.

When drawing up Noise Insulation Regulations for New Railway Lines and an associated Technical Memorandum, the Department will be seeking technical assistance from the Chairman of the Committee, Dr Mitchell, other members of the Committee and representatives of the railway operators. This group will also be asked to consider further whether it would be appropriate and practicable to include a maximum pass-by noise standard in these Regulations.

The Department will consult on a draft of the Regulations before they are made.

The full text of Mr Freeman's Parliamentary Answer is attached.

NOTES TO EDITORS

1. The setting up of a Committee to recommend a noise insulation standard for dwellings near new railway lines was announced on 23 March 1990 (press notice no. 92). The Chairman of the Committee was Dr Kit Mitchell of the Transport and Road Research Laboratory.

2. The terms of reference for the Committee were

"to recommend to the Secretary of State for Transport a national noise insulation standard (or standards) for the operation of new railway lines which equitably relates to the standard set by regulations for new highways".

3. The publication of the report of the Committee was announced on 27 February 1991 (press notice no. 47).

4. The Committee's recommendations included the following on noise standards for new railways:

Recommendation 2 The noise level near the track should be determined using the A-weighted scale and expressed in terms of the equivalent noise level $L_{\text{Aeq}}$ averaged over a specified time period.
Recommendation 3 Those responsible for a new railway should have a duty to offer to insulate against noise those rooms of dwellings near the new railway line that are exposed to a facade noise level from the railway of at least 66 dBA $L_{A_{eq},24hr^{-}}$.

Recommendation 4 Those responsible for a new railway line should also have a duty to offer to insulate against noise those rooms of dwellings near the new railway line that are exposed to a night-time facade noise level from the railway of at least 61 dBA $L_{A_{eq},night^{-}}$. Equity with roads would require that the period of night should be the six hours from midnight to 0600. However, for compatibility with the definition of night used in the context of airport noise (where the intermittent noise provides a closer comparison with rail noise than does noise from road traffic), and for acceptability to trackside residents, the Committee recommends that the requirement for equity be relaxed and that night be defined as 2300 to 0700 hours.

Scales and indices used for road and railway noise

5. Various scales and indices can be used to describe the variability of a fluctuating noise level. The $L_{A_{10}}$ level (the noise level in dBA exceeded for 10% of the time) is used for measuring road traffic noise in the UK. For the purposes of the Noise Insulation Regulations, which are applicable for road traffic, the index used is the arithmetic average of the 18 hourly values of $L_{A_{10}}$ determined over the period from 6am until midnight on a normal working day. The noise index formed by this average is written $L_{A_{10},18hr^{-}}$.

6. The equivalent continuous sound level, $L_{A_{eq}}$, which is particularly suitable for describing a noise which consists of occasional short periods of noise between long relatively quiet periods, has been adopted by British Rail for the assessment of railway noise. $L_{A_{eq}}$ describes the level of (hypothetically) steady sound that, over the period of measurement, would deliver the same noise energy as the actual intermittent or time varying noise. When quoting the $L_{A_{eq}}$ it is important to stipulate the time period over which the measure applies. For example if the time period is 24 hours the equivalent continuous noise level is usually written $L_{A_{eq},24hr^{-}}$.

7. Noise measurements generally use the logarithmic scale of the decibel (dB). The sensitivity of the human ear is not uniform and, to take account of this, weightings can be used to reflect the varying emphasis given by the ear. The most widely used is the A-weighting; hence "dBA".
"In my reply to the hon Member for Sevenoaks (27 February 1991, Col 507) I said that, before deciding on the Committee’s recommendations, we would like to have the views of railway operators and other interested parties. We have now considered the views received and have come to the following decisions on the Committee’s main recommendations. Our aim has been as far as possible to achieve equity in the noise insulation standards applying to new roads and new railways. But as was evident from the Committee’s report, this is a field in which there is room for different opinions.

"We accept the Committee’s view (Recommendation 1 in the report) that those responsible for new railway lines should take all reasonably practical steps to reduce noise in the corridor along the line, provided that they are cost effective.

"We accept that there should be a nighttime noise insulation standard for noise from new railways as well as a daytime standard (Recommendations 2, 3 and 4). We have decided that, in line with the existing noise insulation standard for new roads, daytime should be defined as 0600 to midnight, and that the levels should be 68 dBA$_{L_{Aeq}}$ 18 hr for day and 63 dBA$_{L_{Aeq}}$ 6 hr for night. 68 dBA$_{L_{Aeq}}$ 18 hr is a straight conversion from the 24 hour level recommended by the Committee. In the case of the nighttime standard, both British Rail and the Transport and Road Research Laboratory have carried out analyses of more sets of road noise data than were available to the Committee. Our decision that the nighttime standard noise for railways should be 63 dBA$_{L_{Aeq}}$ 6 hr reflects the outcome of those later analyses.

"We accept in principle that the detailed operation of the noise insulation standards for new railways should follow as closely as possible the system already provided in the Noise Insulation Regulations 1973 (as amended) in the case of new roads (Recommendations 5, 6, 7, 8 and 11).

"The Committee identified a number of other items that would need to be specified in any regulations, (Recommendations 9, 10, 12 and 13). We shall consider these recommendations when drawing up Regulations to give effect to the noise insulation standards. In drafting the Regulations and an associated Technical Memorandum, the Department will seek the technical assistance of Dr Mitchell and some of the members of his Committee and of representatives of the railway operators. We shall also ask this group to consider further whether it would be appropriate and practicable to include a maximum pass-by noise standard in the Regulations (Recommendation 15), though it would go beyond strict equity with the current statutory position relating to noise from new roads.
"We accept Recommendation 14 (that any future change in the noise level for the insulation of houses near new roads should be matched by a corresponding change for houses near new railways). We hope to commission next year a review of the data from road noise surveys to see whether there is any evidence of a shift in social attitudes towards road traffic noise. If such evidence emerges, we will consider the need for a large scale study to determine whether there is a case for revising the noise insulation standard for new roads. We also accept in principle that when a new railway line is opened the opportunity should be taken to obtain evidence of the response to noise from new railway lines (Recommendation 17). In the light of the evidence from the various studies, it may be appropriate in due course to review the relationship between the standard for new roads and those for new railways.

"We are considering the implications of bringing some non-domestic buildings within the scope of the road noise insulation regulations; any change will be reflected in the Regulations for railways (Recommendation 16).

"We shall consult on a draft of the regulations before they are made."

Press Enquiries: 071 276 0888; out of hours: 071 276 5999
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