THE APPLICATION OF L_{Aeq} TO RAILWAY NOISE

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1. INTRODUCTION

Noise is, by definition, unwanted sound. It may be annoying, it may interfere with speech communication, leisure or relaxation, or, at very high levels, it has the potential to cause hearing loss.

Noise is a major factor in dissatisfaction with the environment in residential areas. This has led to the development of methods of assessing the impact on the community of noise from a variety of sources, and in particular from transportation systems, which are the most widespread noise sources in the developed world today. The number of road vehicles trebled in OECD countries between 1960 and 1980 and air traffic doubled in the same period. Urban populations have increased by 50% and the number of towns and cities with over 1 million inhabitants has doubled. Motorways, airports and large-scale transportation facilities have been constructed.

In the UK in the mid-1970's, 50% of the population was exposed to road traffic noise levels above 55 dB(A) L_{Aeq}; at 60, 65 and 70 dB(A) the percentages were 27, 11 and 4% respectively. Average exposure has increased since then. It was estimated in the mid-1980's that in the 12 major developed countries, 17% of the populations were exposed to 65 dB(A), a level judged to be unacceptably high (15% to road traffic noise, 1% to aircraft noise, 1% to railway noise). This amounts to 135 million people in the OECD countries, and will thus affect about 54 million homes.

Noise annoyance may be defined as a feeling of displeasure evoked by noise. The annoyance-inducing capacity of a noise depends upon many of its physical characteristics including its intensity, frequency characteristics, and variations of these with time. However, annoyance reactions are sensitive to many non-acoustic factors of a social, psychological, or economic nature and there are considerable differences in individual reactions to the same noise.

The level of community noise is measured using the dB(A) scale, but the maximum level (L_{Amax}) originating from a source is not the only consideration; duration is also important. Sometimes single events are relevant (for example, in the case of aircraft or train noise), whilst on other occasions, such as motorway noise or factory noise, the noise is more or less continuous. So, where separate noise events are clearly distinguishable, the important factors are the maximum level and duration of each event and the number of events in a given period, whilst 'continuous' noise is averaged in some way over the exposure duration. Different descriptors have been derived to describe the different temporal characteristics of the different sources. The most widely used descriptor for transportation noise is L_{Aeq}, which can be used for rating all transportation noises (although the UK standard is expressed in L_{10}; for busy roads, L_{Aeq} is about 3 dB below the L_{10} value), including railway noise. However, equal values of L_{Aeq} for different sources do not necessarily elicit the same community reaction. Research has shown, for example, that levels of annoyance from railway noise are somewhat less than annoyance from road traffic noise of the same level. The different characteristics of the noise, both temporal and spectral, are factors which play an important role in determining response, which cannot be adequately described by a measure of the noise alone. These differences are normally taken into account when defining standards.

2. STANDARDS FOR RAILWAY NOISE

International noise standards are generally designed to control the noise emitted by specific machines, such as aircraft, motor cars, trucks or industrial equipment. Environmental noise control standards or legislation are, on the other hand, normally devised by national or local authorities to provide an acceptable noise environment for their specific conditions. Thus, *traffic* noise limits depend not only on the noise emitted by each individual *vehicle* (for which limits may be specified by international standards), but by the number of vehicles using the roads, their speed, the distance from the road and so on, which are a matter of local concern. Individual vehicles will not be separately identified within the total noise environment, and it is unlikely that any single vehicle would make a major contribution to the noise level on its own.

A number of standards organisations exist and it is useful to distinguish between them and the force that each has.

The International Organization for Standardization (ISO) issues standards which are related to definitions, measurement methodology and descriptions of noise levels. They may not be mandatory but are helpful documents that enable descriptors and measurements reported by different laboratories to be comparable. The International Electrotechnical Commission (IEC) publishes standards that are normally complied with in electronic instrument manufacture.

Standards developed by the British Standards Institution have similar status to ISO documents and may in fact be identical to them. Most UK manufacturers and laboratories conducting tests will produce products and adopt procedures that conform to the standards, or to those standards in force in those countries where the product or information is to be used.

The European Community produces Directives which are mandatory and have legal status within the EC. These may relate to noise levels emitted by specific sources or to noise levels received by an individual or community. Once implemented, these levels must be complied with. The standards are not necessarily defined to establish an "ideal" noise level but may have been set to ensure conformity within the Community and to remove potential trade barriers.

2.1 Standards for Railway Noise in the Community

Noise descriptors are used to relate community response to noise level. Combined noise and social surveys have helped to define levels at which specific responses can be expected and which, in turn, can be used to define noise standards.

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A number of countries have defined standards of recommendations for railway noise, but the levels at which these are set are influenced by a number of factors, some of which are listed below.

(a) The noise and social survey design will influence the dose-response relationships. For example, the dose-response relationship derived from a study confined to a specific locality may be different to that from a national study because local factors will influence the results. Questionnaire design is also important.

(b) Most studies of railway noise show that, in general, annoyance increases steadily with increasing noise level and no particular "critical" level of noise exposure can easily be defined from the dose-response relationship. Each authority will select its own level for inclusion in a standard or recommendation.

(c) Some standards or recommendations will be based on "acceptability" whilst others may be based on levels that should never be exceeded.

(d) Road traffic noise studies have been more numerous than railway noise studies. In a number of countries, road traffic noise standards have been the base from which railway standards have been derived. A 5 dB "bonus" is often allowed to recognise the lower annoyance caused by railway noise at the same level.

(e) Different legal frameworks have led to different standards.

(f) Some countries favour use of the 'facade' level (1-2 m from a building facade) in standards; others use "free-field" levels. The difference between the two is around 3 dB.

(g) There is widespread agreement that standards and recommendations should be expressed in terms of L_{Aeq}, which has been shown in the majority of studies to correlate better than most other descriptors in common use. However, the period over which L_{Aeq} is described varies; a number of standards and recommendations divide the 24 hours into two or more periods (e.g., day, evening, night). The night-time L_{Aeq} may be reinforced by a maximum noise level in some cases.

All the above factors influence noise levels defined in national standards and recommendations, and a number of standards and recommendations currently used in selected European countries are presented in Table I. It includes only noise standards or recommendations which refer to residential property and differentiates between those which are merely guidelines and those which identify the levels at which insulation of the property concerned is required. It also includes comparable road traffic noise standards where possible.

In the UK, the Minister of State for Transport, in November 1991, proposed noise insulation standards for new railways that follow as closely as possible the system already provided in the Noise Insulation Regulations 1973 (as amended) in the case of new roads. The standard proposed is 68 dB(A)$_{LAeq\ 18\ h}$ for day and 63 dB(A)$_{LAeq\ 6\ h}$ for night. Daytime is defined as the 18 hours from 0600 to midnight.

Guidelines for new railways are defined in Denmark but there are no specific provisions for acoustic insulation if they are exceeded. However, the Government helps to fund insulation of properties affected by noise from existing railways and a similar policy is likely to be adopted for new railways. In Norway, the establishment of standards for new railways is under discussion, but the Government already provides funds for insulation to reduce the noise impact of existing railways. In view of the cost of the required insulation, the limit is set at 73 dB (L_{Aeq}). In Sweden, standards for both outdoor and indoor noise levels are set; insulation is provided both for new railways and for alterations to existing lines.

Table I: Noise standards or recommendations for new railways and new roads in a number of countries

Country	Standard, Guideline or Recommendation	Road	Railway [level given in L_{Aeq} unless stated] [Facade: F; Freefield FF]	Time of Day	Note
Denmark	G	58(F)	63(F) 88L_{Amax}	24h 24h	
Norway	R	-	60(F)	24h	
Sweden	S	-	63(F) 30(Indoor,living) 50L_{Amax}(Indoor, bed)	24h 24h 2200-0600	
France	R	60(F)	65-70(F)	0800-2000	1
Germany	S	59(FF) 49(FF)	59-64(FF) 49-54(FF)	0600-2200 2200-0600	1
Netherlands	S	- 55(F) 50(F) 45(F)	60(F) 60(F) 55(F) 50(F)	24h 0700-1900 1900-2300 2300-0700	1,2 1,2 1 1
Switzerland	S	55 45	60(FF) 50(FF)	0600-2200 2200-0600	1 1
UK	S: Road R: Railways	68$L_{A10,18h}$	68(F) 63(F)	0600-2400 2400-0600	1 1

Notes: 1. Insulation to property provided when these levels exceeded.
2. These limits to be reduced to 57dB(A) on 1 January 2000.

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France has no formal legislation relating to noise from new or existing railways, although recommendations do exist.

Germany has recently introduced more stringent standards which apply to both new and "significantly changed" railways. In the latter case, alterations have to result in noise level increases of 3 dB(A) or rise to an absolute level of 70 dB(A) during the day and 60 dB(A) at night. If these noise levels are exceeded, noise insulation is installed in affected properties.

The Netherlands have defined strict noise goals for both new and existing lines. If, on new lines, the goals cannot be met by control at source or by use of trackside barriers, insulation of affected properties is required.

Switzerland also has national legislation relating to railway noise; insulation is provided when the defined levels are exceeded.

The table summarises noise standards or recommendations for *new* railways in a number of countries. Since it is based on information from different sources, and some is currently under discussion, the levels quoted, and their interpretation, may change. However, it is believed to be accurate at the present time.

It is difficult to identify a common strand among the standards other than the use of L_{Aeq}. However, where a road traffic noise standard is quoted it is generally 5 dB above the railway standard, although some countries are re-appraising this, particularly when the railway standard is at or below 60 dB(A). This is not unreasonable because any difference increases with increasing noise levels. At around 55 dB(A) or so, any differential will probably disappear.

Some standards are clearly intended to be "acceptable" whilst others will lead to higher levels of adverse response but which are felt to be reasonable, and take into account other considerations. For example, the standards for existing lines in Norway are influenced by economic factors.

The 24 hour values of L_{Aeq} range from 60 dB to 66 dB. In terms of subjective impact this may not be large but in terms of operational implications it is equivalent to a four-fold change in the numbers of railway operations. This clearly is significant for operators.

2.2 Railway Noise Emission Standards

There is at present no international standard or recommendation for the maximum level of noise emission from the rail/wheel interaction or from the locomotive. It is difficult to define as the emitted level depends not only on the rolling stock itself but on the type and condition of the track on which it runs, which will be beyond the control of the rolling stock manufacturer. If guidance on these matters did exist it could help national authorities to set realistic standards and control measures in the light of the likely mix of international traffic on their railway tracks.

Until international standards are defined, the national railway companies will have to meet different standards as their trains operate within different countries. It will be up to the national authority to ensure that the mix of trains operating within that country will meet their own standards. This could lead to confusion for both operators and legislative bodies. The economic implications are clear; twice as many trains which are 3 dB quieter than others can operate and still produce the same overall noise level. This has important implications both for the authorities and for the operators when standards have to be met.

2.3 Mitigating Measures

In the light of the above, measures to reduce noise levels may be necessary. Noise control may reduce noise at source or attenuate the noise as it is transmitted from the source to receiver. Noise control at source is normally the most effective and efficient method of noise control. However, in some cases, the *individual* source may not be the problem, and excessive noise may be caused by the *number of sources*, or noise events, which can be the case with road traffic. Other control options might include reducing the noise output by operational restrictions, such as reducing train speed or restricting operations to certain times. However, it should be noted that reducing the number of vehicles, or noise events, by half only reduces L_{Aeq} by 3 dB(A).

Controlling the noise level in its path from the source to receiver is another option. The further a noise is from a receiver, the lower the noise level will be (hence siting decisions are important). Also, noise barriers can reduce railway noise levels by up to about 8 dB(A) if they are located carefully. Barriers can be in the form of walls, fences or retained cuts, whilst insulation of dwellings by double glazing may be appropriate in some cases.

3. THE FUTURE

There have for many years been lobbies for the increased use of the railways for freight transport. The underlying reasons for this are environmental concerns, conservation of oil and financial benefits. However, in the current free-market culture and without a major government investment into the railway system this is unlikely to happen in the UK. However, if the number of HGVs on the roads were to diminish dramatically, road traffic noise levels would reduce quite noticeably. It is one of the ironies of the Channel Tunnel development together with the removal of trade barriers within the EC that the number of HGVs on UK roads will increase because of its construction. Whilst the Tunnel is a major link in a pan-European rail network, without the associated national support structure, it will merely create more road traffic in the UK.

However, the Community of European Railways, comprising the railway companies of the 12 European Community (EC) members together with Austria and Switzerland, have drawn up plans to establish a European high-speed railway network within the next 20 years. By definition, high speed trains are considered as trains running at 250 km/h or above on new lines and 200 km/h or above on up-graded lines. It is anticipated that the network would form the core of the European transportation infrastructure from the mid-1990's onwards. In France, the TGV has been operating with outstanding success between Paris and Lyon at speeds up to 280 km/h since 1981; a second TGV line opened in September 1989 between Paris and Le Mans, operating at speeds of 300 km/h. Plans are well advanced for the TGV-Nord to Lille and the Channel Tunnel. Italian and German Railways are introducing high speed trains and Spain wants to use the French TGV between Paris, Barcelona, Madrid and Seville. A new high speed line from London to the Channel Tunnel will be built to complete the London-Paris/Brussels link, which is seen as the heart of the European high-speed network.

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Although trains are generally perceived to be the safest, most economic and the most environmentally friendly of all conventional transportation systems, many communities are now re-appraising the cost of new railways in terms of environmental impact, with such factors as noise, vibration and visual intrusion coming to the fore. A general increase in public awareness of environmental issues over recent years is forcing developers in every sphere to consider environmental factors more carefully. This has been particularly true with high speed railways; British Rail's proposed link from London to the Channel Tunnel faced severe environmental opposition, which led to a 40 per cent increase in the estimated construction costs. Planners looking to build new rail routes, especially for high speed operation, need to consider many different environmental issues, although noise is held to be one of the most significant factors.

Although the next generation of high speed trains will be no noisier than their slower predecessors, careful planning of the route and noise abatement procedures is still needed to meet environmental guidelines. The majority of existing routes have spare capacity to accommodate the future growth that may accompany improvements in the service and the noise implications of this will need to be looked at carefully.