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THE ASSESSMENT AND MITIGATION OF RAILWAY NOISE IMPACT

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1. INTRODUCTION

Railway noise is one of the oldest examples of the impact of transportation noise on the environment, and yet it is a field in which methods of assessment are still in their formative stages. Major new railway schemes are a comparatively recent phenomenon.

When the first major proposal for a new railway was published in the early 1970s, namely the previous scheme for a Channel Tunnel Rail Link, noise assessment experts had an almost clean sheet of paper on which to begin their task. A number of opposition groups approached the task by going back to basics, predicting noise levels and then attempting to interpret the results in the way that other noise sources were assessed: looking at railway noise in the context of the non-rail background: looking at the effects of absolute levels on task performance, sleep disturbance and annoyance: and making judgements about the impacts. This approach produced conclusions about impact which may or may not have been valid, and in order to seek to calibrate a scale of railway noise impact, the British Railways Board commissioned the well known work of Fields and Walker[1].

2. BRIEF SUMMARY OF UK RAILWAY NOISE IMPACT WORK

The original Fields and Walker results (Reference 1) concluded that the best measure of railway noise impact was L_{Aeq} (24-hour), and that adverse response to railway noise was little dependent on noise level below about 55 dB(A) L_{Aeq} (24-hour); that there was a small increase in annoyance between 55 and 60 dB(A) L_{Aeq} (24-hour); and that there was a progressive increase in annoyance as levels increase above 65 dB(A) L_{Aeq} (24-hour).

An important finding of the study was that it was estimated that railway noise was less annoying than road traffic noise by between 4 and 15 dB(A) L_{Aeq} (24-hour). It noted national differences, however, and observed that Japanese studies indicated that the noise from the (then new) high speed Shinkansen routes was as annoying or more annoying than road traffic noise of the same noise level. The Fields and Walker study dealt only with railways established for many years.

Fields and Walker found that a higher proportion of freight traffic increased the amount of annoyance for the same noise level.

In a more recent paper[2] Walker proposes acceptable levels of railway noise which include 70 dB(A) L_{Aeq} (24-hour) as "Tolerable: when 20% of the exposed population are highly annoyed" and 60-65 dB(A) L_{Aeq} (24-hour) as "Clearly Acceptable: when 10% of the exposed population are highly annoyed". He adds another "Clearly acceptable" criterion for night-time, "if circumstances require special consideration" of 60 dB(A) L_{Aeq} coupled with a maximum noise level of 85 dB(A). These figures were derived from work on sleep disturbance.

If Fields and Walker had carried out their work after the opening of a major new railway line, there probably would be little doubt that the calibrated social survey results obtained, and the noise index used to calibrate the scale of response would, as a means for assessing the noise impact of new railway projects, be as well established today as is the means used to assess the noise impact of new airports or new road schemes. Although the Fields and Walker results are highly respected, they do not, as yet, enjoy the statutory position of the system used for assessing noise from roads, and the way is open to anyone who seeks to devise an alternative method of assessment. Indeed other methods are in use which have varying degrees of justification.

2. THE PHILOSOPHY OF A NOISE ASSESSMENT METHOD

Because several quite different methods of assessing noise from new railway lines are in use, and they sometimes produce conflicting results, it is helpful to pause and reconsider the fundamental facts of the task they seek to perform.

Environmental noise impact is a combination of two types of effect. The first type is purely physical and the second is purely psychological. Between these extremes lie the many complex effects which determine people's responses to noise. At the purely physical end is the influence of noise on speech intelligibility, and nearer the physical end than the psychological end is the important effect of sleep disturbance. Towards the psychological end lies annoyance. It is arguable that even annoyance has a purely physical component, since an inaudible noise should not cause annoyance, and audibility is determined by physical parameters. The physical effects of noise are a function solely of the physical parameters, i.e. level, duration and spectral content. The psychological effects are functions of these parameters only insofar as they are perceived by the listener in terms of loudness, intrusiveness and propensity to cause annoyance which may have as much to do with the meaning of the noise as its physical attributes. Preconditioning and habituation to particular noise sources are important factors.

2.1 The influence of background noise

In this paper, the term background is used to describe all aspects of the noise environment without the railway and is not limited to the background LA90.

In the general field of noise assessment, the noise background can be relevant for three main reasons. Firstly it has an influence on people's expectations; in an area of very low background people feel entitled to peace and quiet and aggrieved at the intrusion of alien noise events. Secondly, background noise may partially or completely mask the noise of potentially intrusive events; if it masks them completely and the event is thereby inaudible then background noise may reduce noise impact. Thirdly, if the background noise is high enough to be causing an adverse impact on people, then if additional noise is added to it the whole noise impact cannot be attributed to the additional noise alone. It is worth examining these three impacts in some detail.

2.1.1 Environmental expectations. Of the three influences of background noise its function in determining people's expectations of their environment is the most difficult to quantify. Where there is no road traffic, people find newly introduced road traffic intrusive; where it is quiet except for the existence of intermittent bursts of noise people may take relatively little notice of the intermittent noise if it is infrequent and still consider it a quiet area because of the low noise level between the noise events. Early work[3] on public response to road traffic noise concluded that the range of the noise climate (e.g. L_{A10}-L_{A90}) was significant.

2.1.2 The masking effect of background noise. Masking is an acoustical phenomenon which is the effect caused by one signal on the audibility of another. It is frequency dependent and quite complex in its action. While background noise can have a masking effect in its true form, and reduce the audibility of a specific source, in a looser sense, background noise can render specific noise sources less obtrusive even if it does not strictly mask them, if they are noise events of the same kind that already exist in the environment, in which case no single noise event may be separately identifiable and the impact is primarily a function of the number of times the event occurs, as much as of the noise level or duration.

2.1.3 The contribution of background noise to total noise impact. It is standard practice in the assessment of noise from road schemes to look not only at predicted absolute levels of noise from a proposed new road, but also at the margin of increase in the total noise caused by the new proposal. In the great majority of cases the background L_{A10} or L_{Aeq} is predominantly caused by existing road traffic noise, and the effect of introducing noise from a new road scheme is to increase the numerical value of the index. Conventions have arisen which attach labels to increases in 18-hour L_{A10}, to the effect that changes of 3 dB are not normally noticeable; 5 dB is a significant change, and so on.

2.1.4 The effect on sleep. The great majority of research work on the effect of noise on sleep reaches conclusions which take no direct account of background noise. In almost all cases[4] sleep disturbance is found to be dependent on either maximum noise level or L_{Aeq}. Background noise would be an influence only to the extent that it determined the total value of the L_{Aeq} level, but the L_{Aeq} index is primarily used to improve upon a simple measure of maximum noise level and take account of the 'oftenness' (to avoid the double meaning of the word 'frequency') of the maximum noise events. The level of the background L_{A90} appears to play no significant role.

2.1.5 The psychological effects. To the extent that a noise may be annoying in the 'dripping tap' sense, i.e. it is the characteristics of the noise which cause annoyance rather than the sound level, the background would be influential only as regards its masking effect.

2.2 The influence of background noise on the impact of railway noise.
In considering the relevance of background noise in railway noise assessment it is necessary to take account of several features of railway noise which it does not share with highway noise. Firstly, a railway noise event has spectral and temporal characteristics which are not shared by other background noise events. Thus, as long as a rail noise event is audible it will be distinguishable from all other environmental noise events. Secondly, for the same L_{Aeq} level, a railway noise environment has much higher maximum noise levels than a highway noise environment. Thirdly, railway noise has a relatively small effect on the L_{A90} level; this is relevant to the extent that the L_{A90} sets a people's frames of reference, and influences their judgement as to whether their environment is basically quiet or noisy.

In environments which do not already experience railway noise, background noise is relevant if it is high enough in level to mask noise from the railway and thereby reduce its audibility. The degree to which a railway noise event causes physical effects such as reduced speech intelligibility is not dependent on the level of the background, except that if the background is already high enough to cause speech interference, then the additional speech interference of the railway noise event may constitute a smaller impact than would be the case if the background were low. It is also possible that a speaker may use a higher voice level, or windows are more likely to be closed in a high background noise.

The conventions of environmental impact assessment require that as a first step in assessing the impact of a proposed development, the baseline environment should be quantified, following which any change in the baseline caused by the development is then predicted. Because L_{Aeq} and the other noise indices can be used to measure any kind of noise (regardless of how the results are interpreted), it is tempting to characterise a pre-existing non-rail environment by measuring the baseline L_{Aeq} and perhaps L_{A90}, and then to quantify impact by calculating by how much the values of these indices would be altered following the development.

Unfortunately, however, studies[5] which have been carried out on the subject of people's reactions to noise from different sources, and to noise from different modes of transport in particular, have indicated that while as index such as L_{Aeq} can be used to measure the quantity of noise energy emitted in each case, people's responses depend not only on the L_{Aeq} level but also on the nature of the source. It follows that the traffic noise background (and with rare exceptions the noise background of most non-rail environments is controlled by road traffic noise) is not necessarily a valid baseline against which to assess the impact of newly introduced railway noise and like is not being compared with like. Only in environments already experiencing railway noise does there exist a true baseline for use in impact assessment.

The question must be asked whether train noise of 65 L_{Aeq} mixed with traffic noise of 60 L_{Aeq}, to give a total of 66 L_{Aeq}, causes more of an impact than would be the case with train noise at 55 L_{Aeq} superimposed on baseline traffic noise at 45 L_{Aeq}, to give a total of 55 L_{Aeq}. The difference between the two cases is that in the first, the overall L_{Aeq} level is increased by 6 dB, and in the second by 10 dB, but there is no evidence in the research results to support the view that in these circumstances train noise at 55 L_{Aeq} causes significantly more impact than train noise at 65 L_{Aeq}; in fact the evidence points to the reverse being more likely.

A system which equates an increase of 5 units up to a total L_{Aeq} of 55 with an increase of 5 units up to a total L_{Aeq} of 75 ignores the fact that at 75 L_{Aeq} the physical effects of the railway noise (such as speech interference and sleep disturbance) may be significant, while at 55 L_{Aeq} they are likely to be insignificant. Furthermore, a system which causes equal of greater resources to be expended on reducing railway noise to 55 L_{Aeq} in a baseline of 50 L_{Aeq} as on reducing noise to 65 L_{Aeq} in a baseline of 60 L_{Aeq} is operating inequitably in terms of pounds per person highly annoyed.

2.2.1 The analogy with aircraft noise. Aircraft noise is assessed by the use of absolute indices. Whether the index be NNI, NEF or even L_{Aeq}, no attempt is made to take account of background noise (although strenuous efforts were made by objectors to the expansion of Stansted Airport to have it otherwise). Because aircraft noise is a major long standing noise problem, there exists a substantial body of social survey data which have been used to calibrate the noise and number indices. When a new airport is proposed, its impact is assessed by considering the populations living within contours of equal noise index value and the likely responses of percentiles of those populations.

Only in cases where an existing airport operation is being intensified, or there already exists aircraft noise from another source, is the margin of increase in the value of the index considered. One of the problems which will accompany the adoption of L_{Aeq} for the measurement of airport noise will be that people will be tempted to 'compare apples with pears' and combine background L_{Aeq} levels with airport L_{Aeq} levels. The answer they get may well be a blood orange. As with railway noise, public response to aircraft noise is not the same as public response to traffic noise for the same value of L_{Aeq}.

2.3 Background noise - conclusions

A review of the fundamental considerations of noise impact provides an understanding of the reasons why research results conclude that an absolute measure of railway noise is the best descriptor, and that the influence of background noise is small. Background L_{Aeq} may be relevant if the events it describes have a masking effect on railway noise, or if it is high enough to have a significant noise impact in its own right. There are arguments in support of a view that the background L_{A90} may be relevant, but it is likely that in residential areas where main line railway noise occurs values of L_{A90} tend to be of the same order and that for this reason it has not emerged as a significant variable. There is as yet no research support for a system which takes either background L_{Aeq} or background L_{A90} into account.

3. ABSOLUTE CRITERIA AND NOISE INSULATION THRESHOLDS

3.1 The position regarding road traffic noise

In the late 1960s it became apparent that the noise impact of new roads on residential property was in some cases great enough to warrant action to mitigate the impact. Following studies by government research laboratories[6], the government announced in 1971 by way of a written reply to a Parliamentary question[7] that it accepted the advice of the Noise Advisory Council, that a level of traffic noise of 70 dB(A) on the L_{A10} (18-hour) scale constituted the limit of the acceptable. At the time, the method of measurement of L_{A10} was by electro-mechanical means, and it was considered that the accuracy of measurement or prediction was ± 2 dB(A). Thus, when in 1973 the Noise Insulation Regulations[8] were made, the qualifying noise level was set at 68 dB(A) L_{A10} (18-hour). Opinions are to be found that the figure of 68 dB(A) was chosen as a compromise because some lobbyists wanted to see the limit set at 65 dB(A); this does not accord with Department of the Environment minutes of committee meetings of the period.

The figure of 70 dB(A) (rather than 68) appeared in the Department of the Environment circular, No 10/73, "Planning and Noise", which quoted the Noise Advisory Council's Advice. However, the statutory position of the qualifying limit of 68 dB(A) has had the effect that it has become established as an important benchmark. For example, local authorities in deciding whether to grant planning permission for new housing pay particular regard to the 68 dB(A) L_{A10} (18-hour) contour, and some adopt a lower figure such as 65 dB(A), although refusals based on exposure to noise of more than 65 dB(A) tend not to be upheld on appeal.

While the statutory position is that highway authorities are obliged to pay the cost of noise insulation to the standard specified in the Noise Insulation Regulations, where existing housing is exposed to noise from new or improved roads of 68 dB(A) L_{A10} (18-hour) or more (subject to a number of subsidiary qualifications), the effect is more widespread. Most highway authorities, in designing new roads, assess the noise impact; and where it is the best approach include noise reducing features such as noise barriers or bunds to reduce, or eliminate, the number of houses eligible for noise insulation.

Highway authorities also have discretionary powers to institute noise insulation schemes in certain circumstances.

3.2 The position regarding railway noise
In contrast to the road construction position, no major new main line railways have been constructed in the United Kingdom in this century. A number of urban railways have been constructed, many involving conversion of existing rights of way; British Rail have carried out a small number of re-alignments of main lines, of which the Selby diversion, in which the East Coast Main Line was diverted at the time of the development of the Selby coalfield, is one of the longest. In isolated cases railway Bill promoters have given Parliamentary undertakings to carry out noise insulation. This occurred in the case of the Selby diversion but was not formally linked to a value on a noise index. During the passage of the London Docklands Railway (Beckton) Bill, an undertaking[9] was given by London Regional Transport to provide noise insulation to the standard of the 1975 Noise Insulation Regulations if the facade noise level was predicted to exceed 65 L_{Aeq} (24 hour) within 15 years.

3.3 Comparisons between noise indices
The noise Insulation Regulations, for road traffic noise, express their standards in terms of the index known as L_{A10} (18-hour); following Fields and Walker it has become general practice to express railway noise in terms of L_{Aeq} (24-hour).

The principal reason for the use of these two different indices is historical. L_{Aeq} was originally a measure of occupational noise exposure, and in the UK it was not until the late 1970s that its usefulness for environmental noise was recognised. Where variable noise levels are more or less random, as is the case with road traffic noise whose statistical distribution is often nearly Gaussian, L_{A10} and L_{Aeq} differ by a predictable amount. Where variable noise levels are very intermittent, there can be little correlation between L_{A10} and L_{Aeq}; you could conceive of a railway in a very quiet rural area where extremely high levels of noise were created for much less than 10 per cent of the time and the L_{A10} index would be the same with and without the railway. L_{A10} cannot therefore be used for measuring railway noise impact (whereas L_{Aeq} can perfectly well be used for measuring road traffic noise).

The 18 hour time period used in traffic noise measurement was introduced for reasons of economy. In the early days, noise measurement was an important part of the traffic noise assessment process, and measurements over the 24-hour cycle were labour intensive. It was found that measurements over 18-hours were a sufficient surrogate for full 24-hour noise measurements, and the L_{A10} (18-hour) index was introduced. This problem does not arise in the case of railways, since train movements occur at known times and L_{Aeq} levels can be calculated from measurements of the passage of each class of train, regardless of the time at which the measurement is made, coupled with knowledge of the number of train movements which are likely to occur.

The fact that both road and rail noise indices do not assess day and night separately implies that noise is just as annoying during the day as during the night. This would be to read too much into the research results on which they are based, and it is more likely that the balance between night-time and daytime traffic in both cases tends to be fairly constant, and in areas where there is a large amount of night traffic there is also a correspondingly large amount of day traffic. It is known that in special circumstances where there is, for example, an abnormally large flow of heavy goods vehicles at night the usual correlations with L_{A10} (18-hour) break down, and the fact that the railway noise study found that a high percentage of freight traffic caused increased annoyance is interesting, bearing in mind that freight traffic is often as frequent at night as during the day.

3.3.1 L_{A10} (18-hour) and L_{Aeq} (24-hour) - numerical conversions. An important difference between the L_{A10} (18-hour) index and the L_{Aeq} (24-hour) index is that the former is always measured or predicted for a microphone position 1 metre in front of a building facade. A correction of +2.5 dB(A) is included in the statutory method of calculation of road traffic noise[10] to allow for this effect (in general acoustical practice, the effect of a reflecting plane is to increase noise levels by 3 dB(A)). The noise measurement made by Fields and Walker, though not entirely remote from buildings, were in general not made at the fixed position of 1m in front of a facade. In comparing the two indices, this must be borne in mind.

If a qualifying noise level for a railway noise insulation scheme were to come about, for practical purposes it would be necessary to make measurements in front of building facades, and a standard correction made to allow for this. It might be expedient to use the same correction of +2.5 dB(A), although, in the Docklands Light Railway's noise policy, the more generally applicable correction of +3 dB(A) is assumed.

It is then necessary to make two corrections to L_{A10} (18-hour) to convert it to L_{Aeq}. The first is to convert from L_{A10} to L_{Aeq}, and road traffic noise of 68 dB(A) L_{A10} (18-hour) typically measures about 65 dB(A) $\pm$2 L_{Aeq} (18-hour)[11]. Then the conversion from L_{Aeq} (18-hour) to L_{Aeq} (24-hour) for most traffic flow distributions is about -1 dB(A). On this basis, therefore, the figure of 68 dB(A) L_{A10} (18-hour) of the Noise Insulation Regulations is numerically equivalent to 64 dB(A) L_{Aeq} (24-hour) measured in front of a building facade or about 61 dB(A) in free field.

This figure of takes no account of the effect found by Fields and Walker, namely that in the UK people found railway noise less annoying than road traffic noise of the same noise level, nor of the possibility that the impact of noise from a new railway may not be the same as the impact of noise from a long established railway. The (road traffic) Noise Insulation Regulations require that the noise of a new road which should be used in determining eligibility for noise insulation should be that predicted to occur 15 years after the opening date of the road. If an analogous requirement were made in respect of railway noise, any doubt as to whether the finding that railway noise in the UK is less annoying than traffic noise should apply in the case of new railways would not arise. Thus, the current practice of adding 5 dB(A) to road traffic noise levels before comparing them with railway noise levels, would be reasonable at least in respect of predominantly passenger railway lines.

Based on the foregoing arguments, the conclusion may be reached that a scheme for providing noise insulation against railway noise which was numerically in line with the Noise Insulation Regulations for road traffic noise would be based on a qualifying noise level of 69 dB(A) L_{Aeq} (24-hour). A figure derived directly from the original Noise Advisory Council Recommendation that 70 dB(A) L_{A10} (18-hour) was the limit of the acceptable (leaving aside the 2 dB instrumental accuracy tolerance which gave rise to the subsequent figure of 68), would be 71 dB(A). Given that the conversion from L_{A10} to L_{Aeq} is subject itself to an accuracy of about $\pm$2 dB, it may be concluded that any figure around 69-71 measured 1 metre in front of a building facade, and based on forecast rail traffic for a date 15 years after the opening of the railway, would be technically supportable.

4. CONCLUSIONS

There are clear dangers in applying intuitive methods to the complex and sensitive matter of assessing the impact of railway noise.

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Railway noise shares with aircraft noise the distinction that it is not a universal feature of the noise environment in residential areas. This is in contrast to road traffic noise which, to a greater or lesser extent controls the background noise environment in most areas. Despite the facility with which the same noise index may be applied to any form of noise, there is evidence that public response to noise from different kinds of noise source of the same L_{Aeq} value depends on the source. There is thus, as yet, no justification for assessing railway noise by comparing predicted levels of railway noise with pre-existing levels of traffic noise.

There is, however, strong evidence to suggest that railway noise, like aircraft noise, should be assessed by means of an absolute measure. Indeed, even in the case of traffic noise, the 'limit of the acceptable' which is used as a basis for noise insulation is determined by reference to an absolute measure. Only where railway noise already exists is it appropriate to compute the margin of increase in the value of the index as a result of the introduction of a new source of railway noise. Clearly, where the non-rail background is at a level which causes it to mask the railway noise, the rail impact may be reduced or even eliminated. But to seek to achieve such masking, by lowering the level of railway noise to within a set margin above the non-rail background, when the railway noise index *per se* indicates a low level of public response, would lead to a misapplication of funds for the mitigation of noise impact.

5. REFERENCES

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