TRANSPORTATION NOISE

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INTRODUCTION

Noise is sound which is undesired by the recipient; that is, any sound which intrudes or disturbs or annoys. People will generally tolerate a certain amount of noise. Limits which are imposed for regulatory purposes have to be defined in terms of a measure of noise exposure which accords with the magnitude of people's response. A number of different measures are used at present in the United Kingdom in respect of different types of noise source (road traffic, aircraft, the construction industry and other industry). These measures take account of the various qualities of the noise found to be disturbing to the community at large. But the multiplicity of noise measures tends to be confusing and comparison between them is difficult. It is the purpose of this chapter to review existing noise measures and to suggest ways in which scales can be used to apply to noise from a variety of different sources.

It is useful to differentiate between the terms units, symbols, scales and indices required for the quantitative description of noise. The terms occur frequently in the literature often without distinction and can be confusing. The term "unit" refers to the basic physical measure; for example, sound pressure level denoted by the symbol dB. Noise "scale" refers to the combination of physical parameters (sound pressure, time, etc.) which contribute to people's overall response (e.g., L_{10}, L_{eq}, etc.) Noise "index" is used for the numerical description of noise in which other factors are superimposed on the scale numbers describing the physical quantity noise exposure as defined above. An index may be considered as an adjusted scale to be used as a basis for rating or assessment in planning and in regulations. The additional factors entailed in an index are generally of the kind which imply differences of people's reactions according to the circumstances or time at which the noise is heard. Whereas a scale of measurement may be fixed on the basis of general principles, the definition of an index may be susceptible to alteration from time to time without implying a fundamental change in the scale of measurement to which it belongs.

A "criterion" refers to a particular level of a noise index which is used to describe the likely reaction of a group of people. For example, at a given value of a particular noise index it is expected that a given percentage of persons will react in a certain way. As the value of the index changes these percentages and reactions will change. Thus a level of noise index can be chosen above which the reaction is deemed to be unacceptable; this is defined as a certain criterion level. For traffic noise, for example, a criterion of 68 dB(A) $L_{A10,\ 18\ h}$ is defined in this country as being the maximum acceptable level of traffic noise.

The auditory magnitude of noise is essentially an instantaneous quantity; that is to say, its numerical value in general varies from moment to moment. Measures of auditory magnitude are normally of two types. One type is the weighted sound pressure level of which there are a number of examples, and the measure which is most widely used is the A-weighted sound level (L_A). The other type of measure embraces examples which are defined primarily in subjective terms. Examples include loudness level (of which the unit is the phon), speech interference level and perceived noise level.

INDICES USED IN THE UNITED KINGDOM FOR DESCRIBING TRANSPORTATION NOISE

The major sources of noise at present in the United Kingdom are noise from road traffic, air traffic, railways, the construction industry and industrial premises. In some cases the noise source is subject to planning control and regulation. These transportation noise sources and the index used to describe them will now be discussed.

Road Traffic

Social surveys have shown that dissatisfaction towards traffic noise expressed by people in their homes depends on the level and variability of the noise. The *traffic noise index* (TNI) was shown to correlate with average dissatisfaction [1]. TNI combined a measure of background level with a measure of the difference between traffic noise peaks and background noise.

However, the prediction of TNI is difficult and its measurement is subject to uncertainty because the background noise may come from sources other than the traffic on the road being considered. The value of any noise index lies in its ability to predict future noise environments and because of this problem and the measurement problem, the TNI has been replaced by the $L_{A10,\ 18\ h}$ index as the unit to be used for noise legislation [2]. This unit is based on the L_{A10} scale which gives a measure of level of noise exceeded for 10% of the time. It is determined by the traffic noise peaks. $L_{A10,\ 18\ h}$ is the average of the values of L_{A10} in dB(A) for each hour between 0600 and 2400 hours on a normal working day. Detailed methods for its prediction and its measurement have been prepared; its measurement is straight forward. The index gives satisfactory correlation with average dissatisfaction although it ignores background noise which was accounted for originally by the TNI.

In recent years, it has also been concluded that L_{A10} is closely correlated with L_{Aeq} and thus the latter is often now used to describe road traffic noise, although not with respect to legislation.

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Air Traffic

Aircraft noise is different to road traffic noise in that there are individual noisy events occurring at intervals followed by relatively low noise levels. A social survey was conducted around Heathrow Airport in 1961 and it was found that the daytime annoyance caused by noise from air traffic correlated with the average value of the maximum perceived noise levels and with the number of aircraft heard in a period from 0600 until 1800 hours [3]. The NNI was derived which combined the two quantities according to the formula

$$NNI = L_{PN(max)} + 15 \log_{10} N - 80$$

where $L_{PN(max)}$ is the average (taken logarithmically) of the maximum perceived levels attained during the passage of successive aircraft and N is the number of aircraft heard in the defined daytime period. For an aircraft to be classified as heard and taken into account for evaluation of NNI the maximum perceived noise level at the position in question must exceed 80 PNdB.

NNI has been adopted as indicating the extent of disturbance for aircraft noise at busy commercial airports. The noisiness and number of aircraft heard at a point on the ground are likely to vary from day to day as weather conditions change and the direction in which the airport runway is operating changes accordingly. There will also be significant changes with the time of year as air traffic density varies. For planning purposes long term average values of daytime NNI during the peak summer period (mid-June to mid-September) are used and these can be predicted given the knowledge of air traffic and its routing.

It should be noted that Heathrow is a unique airport in the United Kingdom and the general noise environment is peculiar to that airport. Whether the NNI concept should be used at other airports which have different traffic patterns and different background noise environmnents has been questioned. Whilst NNI contours can be drawn for any airport, the contours alone may not allow the specific community reaction for that neighbourhood to be predicted precisely.

A further criticism of NNI is that the measure takes no account of ground running of aircraft, which can be an important factor in determining community reaction, is excluded from the computation of NNI.

A later study was carried out by the Directorate of Research of the Civil Aviation Authority (CAA) [4] to substantiate the NNI or, if necessary, devise a new index of annoyance due to aircraft noise. It was concluded that a good fit to disturbance responses is given by $L_{Aeq,\,24\,h}$ and that although aircraft movements outside daytime hours should be included in an index they should not be weighted to be more severe in their relative effect than the daytime movements. It was also suggested that a value of $L_{Aeq,\,24\,h}$ of 55 dB "could be used to represent the onset of community disturbance and 70 dB a point of high disturbance".

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In view of this finding, consideration is currently being given to the possibility of replacing NNI by L_{Aeq} as a measure of disturbance from aircraft noise.

In recent years there has been considerable concern about the application of conventional airport planning guidelines in areas affected by noise from General Aviation (GA) aerodromes. The use of standard guidelines (which in the UK are based on the Noise and Number Index) has been questioned because of suggestions that in terms of aircraft noise level (ANL) the annoyance thresholds may be lower due to the multiplicity of different operational patterns, lower background noise levels and different hours of operation. It has been suggested that the repetitive nature of training flights might cause a greater level of annoyance than normal itinerant flights.

Studies of the problem have been carried out in several other countries. The findings tend to indicate that although annoyance due to GA noise is only weakly related to ANL it is relatively higher, for a particular ANL, than air transport (AT) operations.

The most recent study in the UK of GA noise [5, 6], where the noise was described in terms of L_{Aeq}, concluded that, although the relationships between annoyance and ANL were similar for both GA and AT traffic, GA noise appeared to be more annoying. For example, in similar areas experiencing a one-week L_{Aeq} of 55dB(A), near a GA aerodrome one would expect 15% of the population to be very much annoyed. Near an AT airport one would expect 8%. However, this finding must be viewed with some caution because the GA regression was based on very few points.

In general, ANL alone appeared to account for little of the variation in annoyance and non-acoustic factors appeared to play an important role in determining annoyance due to aircraft noise. In this case, higher annoyance was found to associated with feelings that aerodromes are bad with respect to low flying, community relations and in handling complaints, feelings that the aircraft may crash and opinions that leisure flying is unimportant. In addition, respondents who were annoyed tended to be older and more likely to be owner occupiers than their less annoyed counterparts.

Railway Noise

Until the mid-1970's there were few data available to determine the effect of railway noise on residents near railway routes. Concern has often been expressed, however, about the environmental noise problems likely to result from the construction of new routes, the development of land near existing railway lines and when changes in the operating conditions, such as the introduction of faster trains were planned. Recent studies have investigated the effects of railway noise with these points in mind.

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A major national survey of railway noise in Great Britain was carried out by ISVR [7,8,9,10]. Because this represents perhaps the most comprehensive survey in this field the results will be summarised below.

Railway noise was found to be less annoying than road traffic or aircraft noise of equivalent level. In spite of the fact that some people were as severely affected by railway noise as other types of noise, it appeared that on the average, at least in Britain, most people found other noise sources were somewhat more disturbing than railway noise. In terms of extensiveness, it was estimated that roughly 2% of the population of England were bothered by railway noise. Approximately 170,000 people in Great Britain lived at railway noise levels above an $L_{Aeq,\ 24\ h}$ of 65 dB.

The $L_{Aeq,\ 24\ h}$ appeared to be as adequate a noise descriptor as any other studied. No evidence could be found to support ambient noise level or night-time correction factors. At levels of L_{Aeq} above about 45 dB there was a basically linear relationship between noise level and annoyance. Thus there was a steady increase in annoyance with increasing noise levels. There was no particular level of onset of annoyance which could be proposed for current regulations.

In Britain, there seemed to be much less annoyance with overhead electrified routes than with other types of routes. Other characteristics of the operating conditions examined seemed to have little, if any, effect on noise annoyance.

Individual characteristics which were related to heightened annoyance with railway noise included fear of danger from the railway, belief that the noise could be prevented, concern with health effects, recency of house construction and decreasing age of respondents.

Of the various non-through train railway noise sources, the most important was maintenance noise, being rated as more annoying than even through train noise. Vibration was rated as the most important non-noise disturbance associated with the railway, though in this case it was seen as less of a problem than through train noise. Whilst no vibration measurements were available for correlation with reactions, it was found that vibration annoyance was closely related with the logarithm of the distance to the railway. It was influenced by many of the same factors which affected railway noise annoyance.

Among other available information which attempts to relate community response to railway noise are results from surveys carried out some time ago in Japan and in France [11,12]. The Japanese survey was restricted to noise measurements and social surveys carried out along a very high speed track. Their data suggest that it is satisfactory to describe the noise in terms of the maximum L_A during a train pass-by. This seems reasonable as all residents alongside the high-speed railway line were exposed to the same number of trains of a single type. Obviously the railway system that exists in Britain is very different to that considered in the Japanese study. The survey carried out in the suburbs of Paris may bear more similarity to the British situation. The results from the French survey also suggest that the equivalent continuous sound pressure level (L_{Aeq}) is a suitable scale to use to describe railway noise with respect to annoyance. The data showed that if the L_{Aeq} exceeded 68 dB then dissatisfaction was likely to increase significantly.

The evidence from the British and the early French surveys suggest therefore that L_{Aeq} is the most satisfactory descriptor for the assessment of the effect of railway noise. Whilst the French data suggest that a L_{Aeq} of 68 dB might be suitable level of acceptability the British data do not show any clearly acceptable levels, although the author has recently proposed a possible method of establishing criteria for acceptability from these and other data [13].

More recent French work confirms the suitablity of L_{Aeq} as a descriptor of railway noise.

The issue of acceptable levels for high speed railway lines, such as the TGV lines in France and the Channel Tunnel Rail Link in UK, is currently the subject of much debate. At present, no standards for railway noise exposure have been defined in the UK although some other European countries have already done so in terms of L_{Aeq}.

Limitations of the Noise Indices and the Case for a Unified Scale

All the indices described above have been derived for particular noise sources; thus, when each index was derived only noise from one particular source was considered. It is not always possible to use the indices to describe noises for which the index was not originally intended. For instance, L_{10} cannot be used to describe aircraft noise; nor is it possible to use NNI to describe road traffic noise. A situation which occurs very widely in practice is where there is a mix of noises from different sources. For example at Heathrow, road traffic noise and aircraft noise are mixed. Neither L_{10} nor NNI can be used realistically, but it would be advantageous to be able to describe the total noise environment from the various sources. In order to do this, a single noise scale is necessary. Ideally, the scale would enable the above situation to be described adequately as well as allowing noise from road traffic and air traffic to be compared. The scale would have to relate in numerical terms with people's response to noise. It should apply equally well to noise from different sources; it should, if necessary, allow for the influence of background noise to be determined; it should be easily predictable; it should take account of the time distribution of noise; it should ideally be accepted internationally. There is strong evidence to indicate that L_{Aeq} is the most appropriate scale to meet these requirements and, although it is by no means perfect, it has already been adopted in many countries for noise from road traffic, railways and aircraft. The scale provides most of the qualities required of a unified noise scale and in particular it is simple to measure and simple to predict, although it must be stressed that it does not in its basic form meet all the requirements laid out above.

CONCLUSIONS

A number of noise indices and noise scales have been reviewed and the conclusion is drawn that it is possible to use a single noise scale to describe noise from all sources. The most suitable scale at present is considered to be the A-weighted Equivalent Continuous Sound Pressure Level. This scale has the advantage that it is relatively easy to predict and easy to measure. It has, however, disadvantages in some situations. For example, where there are very few noise events the background noise may tend to control the values of the measured or predicted L_{Aeq} and the influence of the single noise event, which may be quite disturbing, may be oversimplified. Another disadvantage is that exposure to the same level of noise (described in terms of L_{Aeq}) from different sources can result in different levels of community response.

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