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Methods for Quantifying the Effect of Noise on People.

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The work presented is part of a continuing effort to improve methods for predicting the impact of aircraft noise upon residential communities around airports. Many attempts have been made to determine the relationships between physical noise exposure, expressed in terms of its average intensity, average duration, number of occurrences during certain periods of the day and so on, and human 'reaction' to it. These efforts may be classified into two basic methods of approach:-

(i) The postulation of basic noise scaling formulae with terms expressing all those factors believed to be of importance, which are then tested and/or refined through continued practical application. The American Composite Noise Rating (CNR), Noise Exposure Forecast (NEF) and their descendent, now recommended by ICAO, Weighted Equivalent Continuous Perceived Noise Level (WECPNL) are examples of noise rating scales developed in this way.

(ii) Direct measurement of the correlation between noise exposure and human response through systematic social surveys. Noise and Number Index (NNI) was derived by this procedure.

Each of these two approaches has its advantages and disadvantages but it is interesting that both have led to similar results. There is general agreement that the variables of first order importance are the noise level, the frequency of occurence and the time of day. However, there is disagreement about the relative importance of these three variables.

This disagreement has its roots in the apparently large variability of human attitudes towards noise. That is, any group of people exposed to the same noise over a period of time will differ widely in their reactions to it. For this reason it is questionable whether any predictive formula, simple or otherwise can be expected to give an accurate estimate of public reaction to aircraft noise. Certainly, there is little to choose between a large number of existing schemes. Provided the calculations are properly interpreted, any one method may be expected to be equally reliable to any other. The fact remains however that all methods are extremely imprecise.

The main questions to be answered therefore seem to be:-

(i) Can the correlation between noise exposure and human reaction to it be improved? Clearly this might be achieved either by redefining the physical noise exposure or by defining 'reaction' in terms which are less variable. A great deal of effort has been spent investigating the first possibility, largely by processes of trial and error. Little attention appears to have been given to the second.

(ii) How is the impact of noise upon people best defined? There can be little doubt that a major factor contributing to the imprecision in airport noise planning is the relatively arbitrary manner in which human response is defined. Words or phrases like 'unacceptable, barely acceptable, moderately annoyed, dissatisfied, very loud, considerably disturbed' and so on are open to much freedom of interpretation and the planner usually finds that the tolerance band within which he must 'use his discretion' is very wide. The numerical attitude scaling which is a necessary part of social survey research has certainly helped to quantify relative reaction but such scales are inevitably linked to an arbitrary datum.

Attempts have therefore been made to remove some of the arbitrariness from such scales of human response. The hypothesis to be tested is illustrated in Figure 1. A 'chain' of community response is postulated where for present purposes 'disturbance' is defined as the direct effect of the intruding aircraft noise. The noise distracts or interferes with human activity and attracts attention to itself. The factors affecting disturbance include the physical characteristics of the noise and its relationship to the pre-existing ambient noise. They also include the nature of the activity interrupted, initially, of course, upon whether it is work, play, rest or sleep. They also depend upon the individual's degree of concentration upon his activity, his hearing acuity and his general sensitivity to noise.

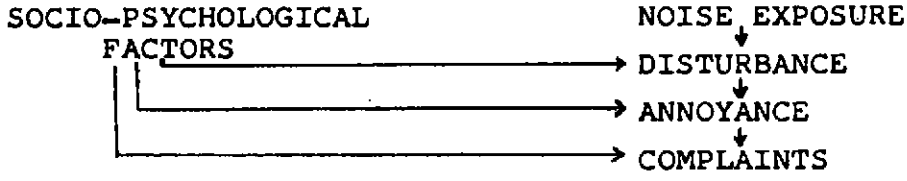

FIGURE 1. Chain of Subjective Response

The indirect effect of noise is to cause annoyance which is defined here as human response to disturbance. Whether or not an individual is annoyed by a disturbance depends, of course, upon its severity but perhaps of even more importance is his attitude towards the source of the noise.

At the third stage of response an individual may take direct action against the noise, initially by complaining. Airport operators usually assess the magnitude of their noise problem from the number of complaints they receive, indeed it is only the complaints which reveal the existence

of a noise problem in the first place. However it is widely recognised that complaint activity is an unreliable guide to true community feeling. This is because complaints tend to emanate from higher social classes, the more influential members of the community who are more articulate and more aware of appropriate channels for complaint. Complainants are particularly sensitive to 'external' pressures, political events and coverage by the news media. Complaints invariably increase whenever changes are made or threatened and die away again soon afterwards.

All factors other than the physical characteristics of the noise environment are grouped together in Figure 1 under the general heading 'socio-psychological factors'. An increasing number of factors interact at successive steps in the response chain implying that more variation of the response variable will be observed. At the 'annoyance' level, for example, the variability, expressed in noise exposure terms, is equivalent to a standard deviation of about 20dB (or 20NNI). That is there will be as much variation of annoyance amongst a group of real people living at a fixed noise level as there would be amongst an imaginary group of identically behaved people exposed to a range of noise with a standard deviation of 20dB (or 20NNI). Clearly the variation of individual annoyance is considerable; indeed it is substantially greater than the variation of average annoyance with noise level.

As a first attempt to reduce this apparent variability it is assumed that an individual's tendency to be annoyed depends upon his general strength of opinion about the many factors which influence his living conditions. It is possible that people who claim to be highly annoyed by noise consider many other features of their neighbourhoods to be undesirable. Conversely, the 'imperturbables', the people who appear completely insensitive to noise, may well be equally unconcerned about other degrading factors. To demonstrate the validity of this assumption a non-dimensional 'noise annoyance coefficient' is devised in which a noise annoyance score is expressed in relationship to an average score obtained for a large number of factors which are unrelated to noise. The correlation between this annoyance coefficient and an appropriate noise exposure index is greater than the correlation between noise level and the non-normalised annoyance score itself. In addition to improving the accuracy with which individual responses may be predicted, this parameter has the added attraction that it directly and properly relates noise to other sources of discontent.

A more direct approach to the problem is to measure disturbance rather than annoyance. Preceding annoyance in the response chain, disturbance should be less sensitive to the intervening factors, and logically therefore less variable than annoyance. Ideally the precise duration of the disturbances or interruptions could provide an essentially 'objective' measure of noise impact. The problem of how to measure disturbance independently of annoyance appears to have no clear solution but the approach adopted is to obtain estimates of the frequency and duration of disturbances during various periods of the day.

If disturbance can be successfully measured, a solution to the 'time of day' problem may result. Previous inabilities to resolve the relative magnitude of the daytime, evening and night-time effects of noise are rooted in the fact that the emotion of annoyance is a cumulative one. That is, the degree of annoyance caused by a specific noisy event depends upon an individual's previous experience. In particular, annoyance expressed during the daytime is influenced by a history of night-time disturbance and vice versa. Partly for this reason, night-time annoyance measured in the 1967 Heathrow Survey correlated equally well with both night-time and daytime noise levels. (A probable contributing factor is that daytime and night-time levels were correlated with each other). Disturbance on the other hand should be much more strongly related to the actual physical noise exposure during the period of interest allowing the ratios between daytime, evening and night-time disturbance to be determined directly.

An alternative method for scaling noise nuisance is to express it in monetary terms. This has been attempted in numerous cost-benefit and cost-effectiveness studies of airport noise and its control, for example, in the analysis performed by the Roskill Commission to select a site for London's Third Airport. Several costs of noise can be identified including soundproofing costs, property depreciation in high noise areas, removal costs incurred by people who choose to move out of noisy areas, loss of 'consumer surplus' (the excess of an owners valuation of his property over its current market price) and finally the detrimental value of the noise nuisance itself. This is perhaps the most difficult cost to define but it may be thought of as the price an individual would be willing to pay to rid himself of the noise or the amount of compensation he would consider necessary to restore his 'quality of life' to the level he would enjoy in a quiet environment. Attempts have been made to obtain estimates of these latter nuisance costs and to relate them to other measures of noise impact.