Proceedings of The Institute of Acoustics

RAILWAY NOISE: NOISE MEASUREMENT TECHNIQUES AND ANNOYANCE REACTIONS

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INTRODUCTION

A nationwide combined noise measurement programme and social survey of railway noise in residential areas in Great Britain has been completed. The widely spread probability sample makes it possible to examine the effects of a wide range of conditions while maintaining high levels of accuracy [1,2]. This useful sample design did, however, necessitate the development of a special noise measurement strategy.

The study collected three types of data: tape recordings of the noise environment, observations of neighbourhood characteristics, and interviews with respondents. Secondary data from the British Railways Board and maps provided other detailed information about the railway operations and site characteristics [3].

NOISE MEASUREMENT TECHNIQUES

The aim of the noise measurement survey was to measure the noise of trains at 403 sites in 75 areas throughout Great Britain. Since it was not possible to measure all the trains passing each of the 403 sites, a special noise sampling technique was developed. Work at ISVR has indicated that, for any train type, there is an approximately constant difference between the A-weighted peak levels measured at two sites close to a given point along a railway route. This finding led to the development of the noise measurement strategy.

In each of the study's 75 areas the basic strategy was to select one "reference site" within about 50 m and in clear view of the railway line. At this fixed site each train passing during the hours of the survey was described, classified and tape recorded. A second set of mobile sound recording equipment was moved through the area during the survey to approximately five "measurement sites". The "measurement site" microphone was placed 1 m from the noisiest facade of a surveyed house at approximately bedroom window height (1.5 m for bungalows, 3 m for most other houses). This "measurement site" data could then be used in conjunction with the reference site data for a few simultaneously measured trains to estimate the constant difference between the noise level at the reference and measurement site. Since an average of five houses with the same noise exposure were grouped around each measurement site, data from the 403 measurement sites could be used to characterize the noise climate at 2010 dwellings.

General use of this strategy enabled the survey to be completed economically and with an adequate degree of accuracy (standard errors of estimate of noise levels will be provided in future reports). Local conditions led to modifications at many sites. Conventional tape recording techniques were used to obtain the noise data.

CALCULATION OF SUMMARY NOISE MEASURES

The results reported in this paper are based on four basic A-weighted sound levels for each pass-by (the maximum sound level; the mean sound level during the loudest part of the pass-by; the maximum rail/wheel noise level; the energy emitted). Subsequent analysis has been more sophisticated, but results are not yet available.

For each train pass-by observed at a measurement site, the difference was calculated between the reference and measurement site levels for both Leq and rail/wheel noise. The mean value of these differences for all trains at each measurement site was obtained. The noise level at the measurement site for every train which had been measured at the reference site was then estimated by adding the calculated reference site minus measurement site difference to each pass-by at the reference site. At each measurement site the logarithmic mean values of the four measures for each train type were calculated and the absolute maximum railway noise level that occurred during the measurement period was estimated. By using working time-table information about the number of trains of each type using the line during four different periods of the day, the summary noise measures were calculated to describe the total noise environment at each measurement site.

The above analysis enabled several noise measures to be determined for each measurement site including the logarithmic mean value for all trains at each site for the 4 basic measures, the 24-hour Leq, the 18-hour Leq (0600-2400), the day-night level (L_{dn}), the community noise equivalent level (CNEL), the Noise and Number index (NNI) (assuming $L_A = L_{PN} - 12$), the highest level recorded from any train.

SOCIAL SURVEY DATA COLLECTION METHODOLOGY

Interviews were conducted by professional interviewers. The 45 minute questionnaire explicitly focused on railway noise only after one-fifth of the interview had been completed. It thoroughly explored annoyance with different types of railway noise and with other aspects of railways. Major recognised, noise-related attitudinal variables were also measured. The questionnaire was specially constructed so as to enable direct comparisons with results of previous noise surveys. Some experiments were carried out on the effect of question wording and order on the results.

OBSERVATIONAL DATA COLLECTION

At the time of the noise measurements two types of observational data were collected: data on the characteristics of each measured train and data characterising the environment at each noise measurement site.

RESULTS FROM SOCIAL SURVEY

A number of conclusions have emerged from the ongoing analysis of the data. More detailed discussions of some issues are included in a previous paper[4].

Evaluating alternative noise indices

To date the railway noise data have been summarised with ten alternative environmental noise indices representing five concepts in noise index construction. The indices were evaluated in terms of closeness of their relationship to annoyance and their ability to incorporate explanatory factors. Increasing the number of events definitely increases annoyance above and beyond the annoyance which could be expected from any of the three average level of events concepts (each pass-by's rail/wheel noise, the single highest peak and the sustained peak level were measured and averaged for all pass-bys) or from the highest peak measured. The relationship between annoyance and number is not clearly either linear or logarithmic. Correlations between accepted noise indices and an annoyance measure suggest that the energy based indices (Leq, Ldn, CNEL) are slightly more highly related to annoyance than is the 12-hour Noise and Number Index (NNI). Neither of the night-time "corrected" indices (Ldn, CNEL) are as highly correlated with annoyance as 24-hour Leq (P=.15). The 24-hour Leq dB(A) is more highly correlated with annoyance measures, including a previously described five item general annoyance index[1] (r = .44), than any of the accepted indices (NNI, Ldn, CNEL, 18 hr Leq, peak level, average noise levels).

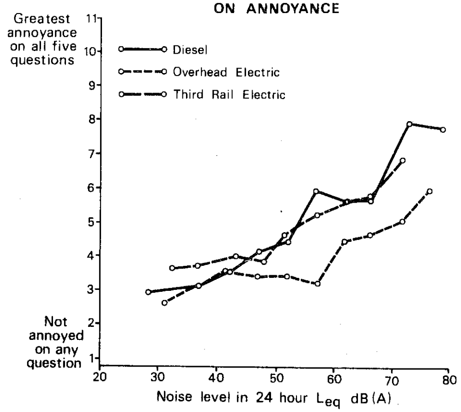
Relation between annoyance and noise level

When over 20 different measures of human reaction to railway noise were examined it was found that though annoyance increases with noise level, the type of relationship depends upon the annoyance concept and even upon the particular questionnaire item used. Above 45 dB(A)Leq there appears to be no particular 'acceptable' level or point of onset of annoyance. This essentially linear relationship for Leq also is true of the other noise indices discussed.

Traction type

Annoyance has been examined under three types of traction conditions: overhead electrified routes, third rail electric routes and exclusively diesel routes. There is no difference in the reactions to different traction types at below 45 Leq. At higher levels the Figure shows that overhead electrified routes are quite significantly less annoying, while third rail electrified routes are only slightly less annoying than the diesel routes. Very extensive attempts have been made to explain this difference in reactions. It appears that the differences are not to be explained by any of the following variables: presence of jointed rail, proportion of freight traffic, ambient noise levels, population density, train speed, number of trains, region of country, visibility of railway structures, fear of electrified third rail, annoyance with fumes, or annoyance with dirt from the railway. Some evidence suggests that the noise from motors of standing trains may affect the evaluation of traction types. Two possible explanations which still are to be explored have to do with the effect of the strong low frequency content of diesel noise and the relative unpredictability of diesel noise levels.

EFFECT OF TRACTION TYPE ON ANNOYANCE



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Comparing the relative annoyance from railway and other transportation systems

Evidence from a DOE survey indicates that in England about 2% of the population is bothered by railway noise. Railway noise obviously annoys many fewer people than road traffic noise (23%) or aircraft noise (13%). The data from the railway survey indicate that in Great Britain approximately 100,000 to 200,000 people in 40,000 to 80,000 homes live at railway noise levels above 65 Leq.

Annoyance with particular levels of railway noise in this survey has been compared with three UK aircraft noise surveys[6,7,8] and two road traffic[5,9] surveys. Considerable care was taken to ensure that railway annoyance questions and noise index construction methods were matched with those used in other surveys. Attention was also directed at the different annoyance conditions (time of year, location in country) surrounding each study. The final comparisons indicated that in every case at high noise levels railway noise was less annoying than the other noise source. However, the size of the difference varied enormously from the equivalent of 1 to 25 dB depending upon the survey being compared and the assumptions made in creating comparable measures. No clear explanation for the sizes of the differences has been found.

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