CORRELATION BETWEEN ANNOYANCE AND NOISE LEVEL ON AN URBAN LIGHT RAIL SYSTEM

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1. INTRODUCTION

The Docklands Light Railway (DLR) opened in London in August 1987. From the time that trains were first tested on the railway local residents complained about the noise due to the trains. A preliminary noise survey showed that in places along the railway high levels of low frequency noise occurred [1]. The places where the low frequency content of the noise spectra was dominant were in general near new lightweight steel and concrete viaducts, and it seemed that most of the complaints about the noise were in areas adjacent to these viaducts.

A more detailed survey has been carried out to try to determine whether it was in fact the low frequency noise that was causing most annoyance. A social survey has been carried out in areas near the railway to assess the attitudes of local residents to the DLR, and to determine the extent of annoyance and disturbance caused by the train noise. At the same time a noise survey was carried out in order to be able to examine the relationship between annoyance and noise levels. During the noise survey the full spectral content of the sound was considered in addition to measurements of L_{Aeq} levels which are generally used as the parameter for prediction of noise annoyance.

This paper reports some observations arising from an analysis of the survey data. An attempt is made to relate the findings of this survey to those of previous studies of community response to traffic noise.

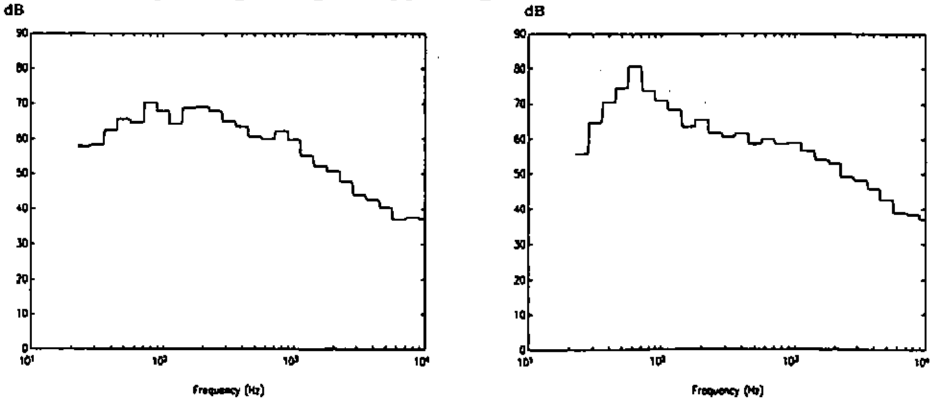
2. THE SURVEY

Sixteen residential sites along the railway were chosen, and residents at those sites asked to fill in questionnaires to determine the extent of the annoyance caused by noise from the DLR. Valid responses were obtained from a total of 149 residents, distributed over the sixteen sites. A detailed description of the respondents can be found in reference 2. In addition to questions concerning annoyance and interference caused by the DLR noise, the respondents were asked general questions relating to their impressions of the area, length of residence and so on. The questionnaire was designed to also explore general attitudes to the railway, and to other commonly recognized types of environmental noise.

The choice of sites was such that all the dwellings targeted were approximately the same distance from the railway. At each site recordings were made of the noise of several trains passing various different points near dwellings. The average third octave spectrum of the individual train passes was determined, together with the spectrum which gave rise to the maximum linear level recorded. The average spectra were used to represent the noise of a typical train bypass as experienced by all the respondents at a particular site. The equivalent continuous sound levels for various different time periods were estimated from the average single event levels and the published DLR timetable. The average, maximum, and equivalent sound levels at each site were determined in linear dB, and using the 'A', 'B' and 'C' weighting scales.

3. LOW FREQUENCY NOISE

In general there are eight different types of track on the DLR, with a particular feature being the lightweight supporting structures.



a). b).

Figure 1. Typical average noise spectra:
a) - measurement location near a ground level track;
b) - measurement location near a viaduct.

CORRELATION BETWEEN ANNOYANCE AND NOISE LEVEL

The analysis of the noise of the DLR trains at different sites showed that the most noticeable difference in the spectra was due to the presence of the new viaducts. Spectra recorded near these viaducts showed high levels in the third octave bands from, typically, 50 Hz to 125 Hz, compared with spectra recorded at other sites. Figure 1 shows two examples of average spectra, one recorded near ground level track and the other near a new viaduct. It can be seen that in the examples shown there is a difference of up to approximately 10 dB in the spectra at frequencies below 100 Hz.

4. CORRELATION BETWEEN NOISE AND ANNOYANCE

The questionnaire responses for each site were averaged to give one set of response data per site. In order to estimate the influence of the spectral content of the noise the responses for each site were correlated with the averaged noise level L_{av}, the maximum level L_{max}, and the 24 hour L_{eq} expressed in linear dB, dB(A), dB(B) and dB(C) at each site. Table 1 shows the correlation coefficients obtained when the noise levels are compared with the average annoyance score at each site.

Level\Weighting	Linear	A	B	C
L_{av}	0.54	0.32	0.42	0.53
L_{eq} (24h)	0.43	0.27	0.32	0.41
L_{max}	0.39	0.09	0.30	0.39

Table 1. Correlation Coefficients between Annoyance Score and Noise Levels

The highest correlations were obtained when the noise levels were expressed in linear dB, and the lowest when the overall noise level was measured in dB(A), thereby supporting the suggestion that the low frequency noise is an important factor in the annoyance caused by noise from the DLR.

The correlation coefficients were also found between noise levels and other indicators of reaction to the noise, such as the percentages of respondents annoyed at each site; frequency of interference with everyday life; and the percentages of people who claimed to be affected by the DLR noise in any way. Again the highest correlations occurred for the noise levels expressed in terms of linear dB, and the lowest ones for the dB(A) levels, providing further evidence that the low frequency noise is a significant factor in disturbance. Table 2 shows the correlation coefficients between these indicators and the noise levels expressed in linear dB and dB(A) levels. These results are described more fully in reference [3].

Response \ Noise Levels	Linear dB		dB(A)	
	L_{av}	L_{eq}	L_{av}	L_{eq}
Annoyance score	0.54	0.43	0.32	0.27
Percentages annoyed	0.58	0.46	0.37	0.31
Percentages affected	0.59	0.49	0.30	0.25
Frequency of interference	0.54	0.47	0.42	0.42

Table 2. Correlation Coefficients between Disturbance Indicators and Noise Levels.

5. NOISE - ANNOYANCE RELATIONSHIP

Although it is recognized that the sample size in this study is too small to provide statistically significant results, regression lines of the annoyance - noise level relationship have been calculated in order to compare the results of this survey with those of previous studies of response to traffic noise. Figure 2 shows the regression line for the relationship between annoyance and DLR noise expressed in terms of 24 hour L_{Aeq}, at all sixteen sites (line 1).

The sites have also been divided into two groups: those where the noise is predominantly low frequency, defined by a difference of more than 10 dB between the linear dB and dB(A) levels; and those where the typical spectrum of the train noise is comparatively flat. The regression lines found for the two separate groups are also shown in figure 2. It can be seen that the two lines are very different, suggesting a much more rapid increase in annoyance with noise level expressed in dB(A) when low frequency noise is present (line 2) than at the other sites (line 3).

6. COMPARISON WITH OTHER SURVEYS

It is interesting to relate the results of this survey to those of previous surveys of response to railway and road traffic noise. We do not pretend here to carry out a direct comparison because of the small sample size in this survey, a

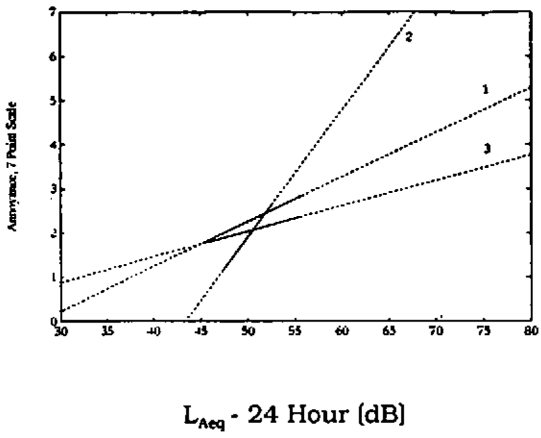


Figure 2 Regression Lines of the DLR survey.

different style of questionnaire and different answer scales. Nevertheless, by scaling the results to make the annoyance score compatible with those of other surveys, it is possible to observe certain similarities in the regression lines.

The results of several surveys of response to rail and road traffic noise are discussed in reference [4]. Figure 3 shows the regression lines of two of these surveys.

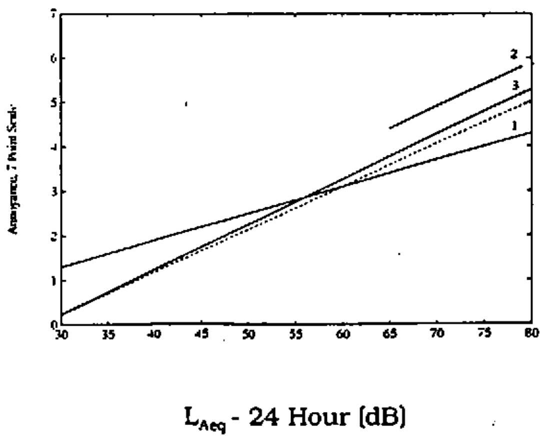


Figure 3 Comparison of DLR survey with other surveys.

Line 1 demonstrates the results of the railway noise survey presented by Fields and Walker, and line 2 shows the results of the BRS survey for congested road traffic. The regression line of the overall data obtained in the DLR survey reported here is represented by line 3. As can be seen from the figure the regression lines of the Fields and Walker railway survey and the traffic survey differ significantly, as do the results of other surveys presented in [4]. However, the regression line of the DLR survey has a slope which is very similar to that of the BRS survey. This could be explained by the significant low frequency content of both the road traffic noise and the DLR noise. On the other hand, the slope of the DLR regression line obtained for the places characterised by relatively flat spectra is similar to that of Fields and Walker as can be seen from figures 2 and 3.

The regression equation between annoyance and noise level expressed as a 24 hour Leq in linear dB has also been calculated for the DLR survey. Fields and Walker [5] calculated separately the annoyance - noise regression lines for three different types of trains included in their survey: overhead and third rail electrified trains and diesel trains. They noted that the noise of diesel trains had a greater low frequency content than the noise of the other types of train. Table 3 shows the regression equations of Fields and Walker [5, table 12], together with those of the overall DLR data, for noise levels expressed in both dB(A) and linear dB. It can be seen that, with the L_{eq} expressed in linear dB, the regression equation of the DLR data corresponds very closely with that found by Fields and Walker for diesel trains.

Weighting	Regression equations							
	Diesel		Third-rail		Overhead		DLR	
	Int.	Slope	Int.	Slope	Int.	Slope	Int.	Slope
Linear	-9.1	0.20	-5.5	0.15	-9.8	0.20	-9.2	0.21
'A'	-3.6	0.14	-4.3	0.14	-5.7	0.15	-4.4	0.16

Table 3. Coefficients (rounded) of regression equations for different train types (11 point annoyance scale).

Another interesting observation follows from the results of some laboratory studies. Persson and Björkman [6] have suggested that the dB(A) scale underestimates annoyance when low frequency noise is present changing the slope of the annoyance - noise level regression line. If a simple correction is made to the regression line of Fields and Walker in accordance with the correction values presented in [6], it can be seen from figure 3 that the slope of the resulting line (shown as a dashed line) corresponds closely with that of the overall DLR regression line.

7. CONCLUSION

The results of the DLR noise - annoyance survey suggest that low frequency noise is a major case of annoyance in this case. It would seem that dB(A) is not a suitable parameter for use in criteria for the assessment of annoyance when low frequency noise is present. It appears that the frequency content of a sound affects the rate of increase of annoyance with noise level and possibly influences the degree of annoyance for a given noise level as may other factors such as the number of events.

Consequently, more consideration should be given to the spectral content of noise in developing common criteria for the assessment of different types of environmental noise.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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