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SUBJECTIVE RESPONSE TO TRAFFIC NOISE IN DWELLINGS ALONGSIDE URBAN MAIN ROADS

G.D. CALLOW

MOTOR INDUSTRY RESEARCH ASSOCIATION

INTRODUCTION

Numerous social surveys have shown that residents would like traffic noise to be reduced. At a given site, this can be achieved by traffic management and by further reduction of the noise emitted by individual vehicles. In the latter case, the motor industry and the legislature are both concerned that the significant penalties involved in meeting reduced type approval levels do lead to real subjective benefits.

It has been suggested, eg Ref 1, that type approval tests exercise insufficient control over traffic noise, particularly as heard indoors after modification by the facade. An investigation was undertaken to: 1) acquire reliable subjective preference scales for traffic noise at the facade and inside the premises, 2) establish an objective measurement procedure that adequately predicts subjective preference and 3) explore the relationship between type approval test results and traffic noise at the facade and inside the premises.

METHOD OF OBTAINING SUBJECTIVE SCALES

At 4 sites, high quality tape recordings of traffic noise were made simultaneously at the facade and in the front room of a house. Thirteen sections of these tapes, each of 30 seconds duration, were selected to cover a range of events indoors from relatively little traffic to very intrusive traffic noise. Two separate pair comparison experiments were carried out in which these events were used as stimuli, one using the room recordings and the other using the simultaneous facade recordings. Thus, two preference scales were obtained which could be directly compared to determine the degree of association between judgments of preference for identical events made at the facade and indoors.

The experiments were conducted in a laboratory facility where the recordings were reproduced accurately over the area in which four subjects sat during each session. With only a few exceptions, the subjects made judgments of preference that were consistent at the 95% level and values of the coefficient of agreement between subjects were satisfactory. For each experiment the aggregate preference matrix was used to obtain a scale of Total Expressed Preferences, namely the number of times each stimulus was preferred to any other by the group of subjects, and this was taken as the subjective rating scale of the stimuli.

CORRELATION OF SUBJECTIVE SCALES WITH STANDARD OBJECTIVE MEASUREMENTS

Leq values were obtained for Sound Pressure Level dBLIN and Sound Levels dBA dBB and dBC over the period of the events (30 sec) for facade and room stimuli.

It was found that subjective preference for traffic noise recorded at the facades correlated well with dBA Leq measured at the facade, r = -0.92 (coefficients for other scales: dBB, r = -0.94; dBC, r = -0.86; dBLIN, r = -0.85) and that subjective preference for traffic noise recorded in the rooms correlated well with dBA Leq measured in the rooms, r = -0.91, (coefficients for other scales: dBB, r = -0.56; dBC, r = -0.43; dBLIN, r = -0.40).

However, the correlation between the two preference scales, facade and room, is not significant at the 95% level, r = +0.48, and a significant correlation was not obtained between room preference and any objective measurement made at the facade. The implication is that a general reduction of traffic noise in the street will not necessarily lead to a subjective improvement inside houses. The reason for this was found by considering the difference in level between facade and room noise.

RELATIONSHIP BETWEEN SUBJECTIVE PREFERENCE AT THE FACADE AND IN THE ROOMS

The lack of correlation between facade and room preference scales arose because the stimuli were selected from recordings made at 4 different sites at which the attenuation provided by the facades differed considerably. For the events used as stimuli, the variance in the attenuations, expressed as dBA reduction, was of the same order as the variance in the facade noise levels. Therefore, the facade attenuation had an important influence on room levels.

Calculating the 10 minute dBA Leq attenuation at each site from the original recordings and applying these to the facade stimuli to predict the corresponding room stimuli is not helpful (r = 0.58). This is because the attenuation at a given site expressed in this way depends on the spectrum at the facade and therefore varies significantly with time.

However the apparently loose relationship between subjective preference in the rooms and that at the facade can be defined quite closely when a sufficiently detailed analysis, ie 1/3-octave band, is obtained of both of the factors that control traffic noise in the home; namely traffic noise at the facade and the attenuation provided by the premises. This gives a correlation coefficient between estimated and predicted dBA Leq of +0.95 and a standard error of 0.75 dBA. Thus the accuracy with which room levels can be predicted from facade levels depends on the detail with which facade attenuation is defined.

CONTROL OF TRAFFIC NOISE AT THE FACADE

The control of traffic noise at the facade depends, for a given traffic flow, almost entirely on the control of the noise emitted by individual vehicles which, in turn, is controlled by type approval testing.

To test the relationship between noise measurements made in the two conditions, four vehicles (a car, a van, a rigid goods vehicle and an articulated HGV) were tested according to type approval procedures and were driven past the 4 sites referred to above under normal urban driving conditions. The maximum Sound Level dBA emitted by the vehicle was measured in each case. The correlation coefficient between the two sets of measurements for the four vehicles at four sites was +0.87.

Moreover, 1/3-octave band analyses revealed that the sources of noise on the vehicles (predominantly broad-band engine noise centred on 1 kHz) that controlled the overall noise emitted was the same in both test conditions. Thus, the results indicate strongly that type approval testing does control the subjectively important levels at the facade.

CONTROL OF TRAFFIC NOISE INDOORS

The A-weighted 1/3-octave band Leq spectrum of traffic noise at the facade, like those of individual vehicles, show a predominant very broad peak centred on 1 kHz. The shape of the spectrum indoors, however, is quite different because of the frequency dependence of facade attenuation which is, say, 22 - 32 dB at 1 kHz but only 2 - 12 dB at 50 Hz. The result in a front room is a spectrum which is broadly flat from 40 Hz to 2.5 kHz with a tendency at some sites for the 50 or 63 Hz band level to protrude by up to 6 dB. Thus the predominant source of noise is again broad band engine noise centred on 1 kHz because the sum of the relevant 1/3-octave band levels will be about 10 dB above the band levels and subjective benefit would be achieved most efficiently by a further reduction of this source, either at source or by fitting double glazing at the site. Thus, the results indicate that type approval testing significantly constrains the subjectively important levels indoors.

However, none of the 4 sites visited in this investigation had the benefit of double glazing. If it were to be fitted, a further 10 dB of attenuation might be expected at frequencies above about 200 Hz and engine intake and exhaust noise at firing frequency would become the subjectively predominant noise which would require attenuation to achieve further subjective benefit indoors.

REDUCTION OF INTAKE/EXHAUST NOISE INDOORS

It has been claimed that low frequency noise is not controlled by type approval tests. This is not the case because the sum of all sources must not exceed the limit. In fact engine noise, being the most difficult to reduce, generally predominates and the contributions of other sources, including intake/exhaust, are, of necessity, reduced to such an extent that the reduction of engine noise is minimised. Further, type approval tests are carried out at relatively high engine speeds, the trend of exhaust noise being to increase at 16 dBA/ doubling of speed, and at full throttle acceleration, the trend of exhaust noise being to increase with load. Thus, intake and exhaust noise are controlled under conditions at which the highest levels are produced and the trend to reduce type approval limits will necessarily lead to lower levels of low frequency intake/exhaust noise, unless a remarkably quiet engine is developed.

However, just as the constraint on noise at higher frequencies is insufficient at certain vulnerable sites and double glazing is installed to provide further improvement, it is clear that some sites exist at which further reduction of low frequency noise (50 - 60 Hz) is desirable and the problem is to decide which site modification will be effective.

SUBJECTIVE RESPONSE TO TRAFFIC NOISE

INFLUENCES ON FACADE ATTENUATION AT 50 - 60 Hz

The 1/3-octave band level differences between the facade and room noise at the 4 sites were lowest at 50 and 63 Hz but the actual values ranged from approximately 2 - 12 dB. An assessment was made of the causes of this difference between sites because of the potential for subjective improvement that a controlled increase would give at a vulnerable site. Unfortunately, a full investigation was beyond the scope of the present work.

Narrow band analysis of the sound pressure level difference between the facade and room at the 4 sites was carried out and compared with the mobility of the window panes and the calculated room modes. The results gave a clear indication of an association between attenuation and window mobility together with room mode frequency but the precise nature of this association could not be defined. An engineering model by which a window could be designed for a given room to give the maximum attenuation could be very valuable. It would allow additional control at specific sites analogous to the specific control provided by double glazing, thus supplementing the general control exercised by type approval testing.

CONCLUSIONS

1) Sound level dBA Leq measured at the facade correlates well with subjective preference for noise at the facade ($r = -0.92$).

2) Sound level dBA Leq measured indoors correlates well with subjective preference for noise indoors ($r = -0.91$).

3) Sound level dBA Leq indoors can be predicted adequately from 1/3-octave band analyses of the two controlling influences, namely facade noise and facade attenuation, but not solely from Sound Level dBA Leq at the facade.

4) On the basis of results obtained from four sample vehicles, there is a strong indication that current type approval procedures control the subjectively important levels measured at the facade and jointly control, together with facade attenuation, the subjectively important levels indoors.

5) A need was identified for an accepted predictive model of facade attenuation in the region of, say, 40 - 70 Hz taking into account the coupled response of window vibration and room modes so that the general control exercised by type approval limits can be supplemented at specific sites, in a manner analogous to fitting double glazing, by selecting a window design to maximise attenuation at low frequencies.

REFERENCES

1. Annual Report of the Scientific Advisor to the GLC, 1974.

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