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URBAN NOISE MEASUREMENT AND EVALUATION

THE EFFECT OF TRAIN NOISE ON THE ENVIRONMENT

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I The Threshold for annoyance by noise produced by trains

A recent acoustical and psychosociological survey of about 350 persons distributed in 20 different locations within about 25 km of Paris gave a scale of the annoyance felt by a person in his home environment. It should be pointed out that the annoyance studied here is essentially a daytime annoyance, because the train noise at the 20 locations was much more frequent during the daytime than the night.

The data obtained shows that among the numerous physical parameters used the energy-equivalent noise level, denoted L_{eq}, seems to give the best correlation* with daytime annoyance. The noise was measured just in front of the facade concerned. However, parameters other than the noise itself have an influence upon annoyance. The individual annoyance index is defined as the percentage of positive responses given by the interviewee to the questions which concern noise. This percentage is given by

$$2,3\ (L_{eq} + 4\,EXPO + 2\ B + 4\ T - 4Q\ ) - 120$$

where $EXPO = \dfrac{\text{Number of rooms exposed to noise}}{\text{Total number of rooms in the dwelling}}$

B characterizes the animosity of the person against noise in general and has values of o, 1 or 2.

T characterizes the animosity of the person against railways and has values of 0, 1 or 2

* A fairly good correlation was also found with the quadratic mean of the peak levels + 20 $\log_{10} n$, n being the daily number of the peak levels. Probably there would also be a fairly good correlation with the quadratic mean + X $\log_{10} n$ where $10 \leq x \leq 20$. For instance, NNI (used in Great Britain for aircraft noise) would give a fairly good correlation with annoyance.

Q characterizes the satisfaction given by the neighbourhood and has values of 0, 1 or 2

L_{eq} is expressed in dB(A).

As an example, a "mean person" for whom B=T=Q=1, the percentage of positive answers is given by 2.3 L_{eq} - 110. That is to say, the percentage of positive answers to the questions concerning noise exceeds 50 when L_{eq} exceeds 70 dB(A).

The data also show that annoyance begins when the energy equivalent noise level (L_{eq}) exceeds 68 to 70 dB(A), and the annoyance increases rapidly when L_{eq} exceeds about 72 dB(A).

L_{eq} depends upon the ratio of total noise duration to the total time considered (for instance, 1 day). Hence, assuming the mean duration of train noise to be 10 seconds* for a high rate of traffic flow upon a double track, that is, assuming 1 train pass-by every 5 minutes in each direction, the difference between the peak level and L_{eq} is about 12 dB(A).

The threshold of annoyance can therefore be expressed as a peak level (or more accurately, the quadratic mean of the peak levels measured in the period considered; for example 1 day). In the particular example quoted, the threshold is equivalent to a peak level of 80 dB(A). Similarly, the threshold for a location near 4 tracks with a high traffic density, would be equivalent to a peak level of 77 dB(A) and would rise to 85 dB(A) in the case of medium traffic upon a double track.

The conclusion is therefore that the prediction of annoyance is better as a result of the consideration of individual motivations. Dispersion of individual responses to noise can be strongly reduced. With the above formula, the correlation coefficient is approximately 0.60 and is a measure of the individual index of annoyance.

This is the first time that considerations of individual parameters have succeeded in France.

(More data is available in the report "ACOUSTICAL AND SOCIOLOGICAL SURVEY TO DEFINE A SCALE OF ANNOYANCE FELT BY PEOPLE IN THEIR HOMES DUE TO THE NOISE OF RAILROAD TRAINS" by D. AUBREE, CSTB and translated by T. SCHULTZ).

II Physical characteristics of train noise

To enable the emission and propagation of noise from trains to be described, 1000 measurements of 200 train pass-bys on a large modern track (Paris-Lyon) in a flat terrain with no houses close by (free field

* This duration seems to be approximately the mean duration of the peak noise levels for passenger trains. This duration is exceeded for goods trains in France, but these have lower peak levels so that goods trains have little effect upon L_{eq}.

conditions) were made. This study, carried out by J.M. RAPIN was reported in the Library Translation 1737 of Building Research Establishment.

These measurements, which involved a fairly representative track in France, were recently supplemented by 750 measurements alongside several tracks leaving Paris. These lines were the same as those used to obtain the annoyance scale. The latter measurements resulted in 3 dB(A) higher values of L_{eq}, measured at the facade, than the 1000 measurements of RAPIN's study.

The analysis of the results gave the change in noise level with increasing distance from the tracks, with train length and with train speed confirming data that are widely accepted.

Data obtained on suburban and express trains on three different kinds of track show that some carriages recently introduced into service are quieter, as well as being more luxurious, (for example, the Trans-Europe Express) than second class trains. In fact, the noise reduction may be as much as 8 dB(A), which is mainly due to the excellent suspension.

The noises emitted by diesel motors are not mentioned in the present paper, because the majority of engines were electric in the 1750 measurements.

A. Quick qualitative analysis of the production of train noise

The reasons for increased train noise are:

Rail joints (when rails are not welded)
Undulating wear of rails (which is remedied by grinding)
Deformation of the wheels, called of roundness or ovalising; more frequent on old or badly-maintained vehicles
Axle load (+3dB(A) on doubling the load)
Speed (+6dB(A) upon L_{eq} on doubling speed, and +9 dB(A) upon peak level)
Bends, (friction between the wheel tyre and the rail head); and slip of the wheels on the rails (rigid axle).
Braking, especially in the case of suburban multiple units train
Diesel motors
Fans (all diesel motors, and the majority of electrical engines)
Siding noise, which may be considered as industrial noise rather than transport noise
Warning devices.

Noise reduction can be achieved by:

Long welded rails (noise reduction about 4dB(A))
Good suspension of the coach structure (in France spectacular examples of noise reduction have been achieved in certain second class and TEE carriages)
Carriages with a skirt masking the wheels
Low screen (1 to 1.5 m) masking the wheels (Ikawa reports that such a screen is highly efficient).

B. Some comments on train noise in France

i) Train noise has a strong directivity pattern, as would be expected if the train is considered as a line of acoustic dipoles.

ii) Train noise decreases with distance as 3 different functions which vary with the distance (d) from the track.

When d <2 x (distance between the wheels) noise level decreases by 6dB per doubling of d.
When d <2 x (length of the train) noise level decreases by 2 dB per doubling of d.
When d >2 x (length of the train) there is again a 6 dB decrease in noise level with doubling of d.

The spectrum is similar for different kinds of electric trains and for the various kinds of track. The speed of the train and the distance from it hardly influence the spectrum. The diesel motor, however, slightly alters the spectrum, adding to the energy to the 125 Hz octave band. The acoustical power level is about 100 dB(A) for a diesel engine standing in the station, which is practically the same as the acoustical power level of a car, and is about 110 dB(A) for a diesel engine under full power, which is almost the same as the acoustical power level of a truck. The motor noise seems rather omnidirectional.

The modern light trains using gas turbines between Paris and Cherbourg seem to produce rather less noise than traditional passenger trains.

3 CONCLUSIONS AFTER THE SURVEY

The results of this survey show again the usefulness of an energy based acoustical index for describing the noise of transportation systems. A similar order of magnitude has been found for annoyance threshold for different systems. The values of this threshold, in terms of L_{eq}, are as follows:

motorway noise and road noise: 65 dB(A) in front of the facade;
train noise: 70 dB(A) in front of the facade;
aircraft noise: 65 dB(A) in front of the facade.

Therefore, the L_{eq} seems very suitable for these cases, as it enables a simple prediction of annoyance to be made. The procedure for reducing the noise to a single index is independent of the type of traffic. This is not so for an index based on a level exceeded for n% of the time. That is, the variation of L_{eq} with $\log_{10}$ of the noise from various sources (that is to say with the traffic) is linear. Hence, the prediction of L_{eq} depends only upon simple statistical assumptions; its application is more precise and universal, and it guards against errors and misunderstanding.