THE ASSESSMENT OF ANNOYANCE DUE TO TRAIN NOISE
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1. INTRODUCTION

In our modern society many people are obliged to live in areas subjected to high noise levels due to the major transportation sources - aircraft, traffic and trains. Much research has been performed in an effort to obtain annoyance assessment scales for aircraft (1) and traffic noise (2) and even a unified assessment scale which applies for several noise sources (3). Relatively few investigations have been orientated towards the specific problem of train noise.

In the past the sound of steam locomotives was thought to be a relatively acceptable, even enjoyable sound. Unfortunately the passing of the steam locomotive has left us with the diesel locomotive which does not possess the romantic image of the old steam locomotives. It is still thought however, that train noise is one of the more acceptable noises, many people being willing (or perhaps obliged) to live close to railway tracks. This opinion is reinforced by the feeling that these people do not complain about train noise. However, many complaints are received by the relevant authorities. A second point is that actual complaints are not thought to be a satisfactory measure of annoyance. Many people may be annoyed but few complain. The work which has been performed on train noise annoyance (4,5,6, all summarized in 7) is of an international nature, studies being undertaken in England, France and Japan. To the authors knowledge no major attempt has been made to correlate annoyance with train noise in Canada. It is often remarked that annoyance is a function of national conditions and traits making the need for local research an important one.

To fulfill the need for an assessment scale for determination of annoyance due to train noise a project was instituted by this Ministry. The work was performed by five Seneca College students under the supervision of the Noise Pollution Control Section of the Ministry of the Environment and financed throught the Experience '75 scheme.

The objectives of the project, as relevant to this paper, were to perform noise measurements at various sites close to railway tracks in the Metro Toronto area; to analyze these noise measurements on a day, evening and night basis to yield statistical parameters such as L_{90}, L_{50}, L_{10}, L_1, $L_{0.1}$, L_{eq} (both total site L_{eq} and train alone L_{eq}) and also train parameters such as audible train duration; to perform interviews with people living close to the monitoring locations; to correlate the noise descriptors with the sociological survey results; to choose the most appropriate noise descriptor and finally to construct a train noise annoyance rating scale based on this noise descriptor.

The overall objectives of the project were wide and not confined to the investigation of train noise annoyance. Much socio-economic data were obtained as well as information on the assessment of other noise sources. This report will be concerned only with the train noise aspects of the project. The remainder of the project contains a wealth of information to be reported at a later date.

2. SITE SELECTION

Initially site selection was performed by studying maps to find suitable streets running close to railway tracks (both Canadian National Railways and Canadian Pacific Railways) and avoiding other major sources such as industry and freeways. However, as it was wished to provide a variety of noise backgrounds to the train noise, areas were also chosen with high expected traffic flows-in downtown areas-and those with low expected traffic flows-in suburban areas. The noise background variation was also provided by selecting sites not only directly abutting the railway tracks but also shielded by one or more rows of housing.

It was also felt advisable to vary the class of the neighbourhood to achieve some variety in the income levels of the survey respondents. It was also thought necessary to provide a range of train movements past particular sites.

Final site assessment was performed by a site visit to eliminate sites subjected to temporary noise (construction, road repairs) and to select actual noise monitoring locations (usually trees, telephone or hydro poles). In all, some 19 sites were selected in this way. Adequate success was achieved in random-izing the parameters of: number of train movements, distance from track, noise background to trains and type of neighbourhood despite relatively low number of sites selected.

3. NOISE MONITORING & ANALYSIS

Noise monitoring was performed at each of the 19 selected sites. Portable battery operated analog monitors were used, these being constructed originally for the London-Woodstock attitudinal survey (8), recently modified and rebuilt by the Noise Pollution Control Section.

The sound was detected by a G.R. 1 inch ceramic microphone amplified and passed unweighted to a Uher 4200 Report Stereo tape recorder. The sound sample was recorded on both channels, one channel recording low sound levels, the second high sound levels. This technique was used to extend the effective dynamic range of the tape recorder to some 70 dBA. Calibration was by means of a G.R. 1562 A sound level calibrator producing 114 dB at 1 KHz.

Each site was monitored at least twice, once with a timer unit (which records for 10 seconds every 2 ½ minutes) and a trip level unit (which records all sounds above a preset level). This technique ensured that all sounds occurring on each site were recorded, those repeated very often by the timer unit, and those of a transient nature by the trip level unit.

The tapes were analyzed by playing back on a Uher 4200 Report Stereo tape recorder and passing in two channels to a Gating Circuit which put the high and low sound level recordings back into a single output. A-weighting was also performed by the Gating Circuit. The signal from the Gating Circuit was then passed to a B & K 2305 level recorder and analyzed into 5 dB bands by a B & K 4420 statistical distribution analyzer. The analysis was analyzed further on a Wang programable calculator

to give the cumulative statistical distribution, L_{eq} and σ.

Tapes from the timer unit were analyzed on a day, evening and night basis. Trip level tapes were treated slightly differently. First the whole noise sample on the tape (composed of all events above the preset level) was analyzed and secondly the train noise alone was analyzed. Accurate day, evening and night information could not be recovered from the trip level tapes as short duration events could only be assumed to be equally spread over twenty-four hours. In this report little emphasis will be given to differences between day, evening and night levels, and the train noise results considered on a 24 hour basis only.

After analysis the results for each tape were drawn out on statistical distribution paper and parameters such as L_{90}, L_{50}, L_{10}, L_1, $L_{0.1}$, L_{eq} (total), L_{eq} (trains only), L_{eq} (trains only spread over 24 hours) and train duration per 24 hours were derived.

Successful monitoring and analysis of noise recordings was performed for a total of 17 sites.

4. SOCIOLOGICAL SURVEY

The sociological portion of this project was based on a questionnaire constructed and pretested by Dr. Fred Hall and Dr. Martin Taylor of the Civil Engineering and Geography Departments, McMaster University. The questionnaire was examined carefully by the Noise Pollution Control Section to check on the acoustical background and also by Dr. Cesare Ruscone, lecturer in social research techniques at Seneca College. A few minor alterations were incorporated as a result of this examination.

The questionnaire was broad based, containing questions concerned with overall neighbourhood rating as well as specific noise source questions. Questions were included to assess activity and sleep interference and also annoyance assessment of particular noise sources. It is the latter question which is of primary importance to this paper. The stages of questioning related to the assessment of a noise source were as follows:

(a) What noises are clearly audible to you in this neighbourhood?
(b) How would you rate each of the noises you've mentioned?

The respondent was then handed a card with the following intensity scale:

1. Extremely agreeable
2. Considerably agreeable
3. Moderately agreeable
4. Slightly agreeable
5. Neutral
6. Slightly disturbing
7. Moderately disturbing
8. Considerably disturbing
9. Extremely disturbing

Further questions elicited other noise sources, asked for a

rating in a similar manner and also asked exactly what was annoying about the noise under consideration. These further questions will not be considered in the paper.

Interviewing was performed with approximately 10 persons for each of the 17 sites successfully monitored, making a total of approximately 170 interviews. Interviewing was also performed on weekends to ensure that the survey was not unduly biased towards housewives, men usually being at work during the week.

On analysis the 1 to 9 intensity scale judgements of train noise were split as follows:

    1 to 5   Not annoyed
    6 to 9   Annoyed

The percentage of people annoyed by trains was then calculated for each site. This technique was employed to give better correlations with measured noise levels by taking a coarser annoyed/ not annoyed split rather than the fine 1 to 9 judgement actually asked for. The improvement in the correlation coefficients obtained using this technique was significant.

5. CORRELATION OF SOCIOLOGICAL RESULTS WITH NOISE DESCRIPTORS

The percentages of people annoyed by train noise (derived according to the previous section of this paper) were correlated with the statistical parameters obtained from the taped noise samples for the 17 sites. The correlation was performed at the Computing Centre at McMaster University, Hamilton using a Bio-Medical statistical package developed originally at the Health Sciences Computing Facility, UCLA, California. Typical correlation coefficients were obtained as follows:

Noise Level Descriptor	Correlation Coefficient	Significance Level
L_{90}	(0.21)	-
L_{50}	(0.15)	-
L_{10}	(0.16)	-
L_1	0.57	2%
$L_{0.1}$	0.72	0.1%
L_{eq} (total)	0.68	1%
L_{eq} (trains only, normalised to 24 hrs)	0.72	0.1%
$\log \frac{T}{24}$ (T=audible train duration hours)	0.69	1%

It can be seen from this table that the low level L values-L_{90}, L_{50} and L_{10}-do not have significant correlation with the percentage of people annoyed by trains. This is to be expected as the trains will not add into the cumulative statistical distribution at these levels. However, it may be thought that the higher the background noise levels then the lower the annoyance due to trains. This appears not to be the case as no significant negative correlation was obtained between the lower level statistical parameters and

the percent of people annoyed.

Continuing towards the higher statistical parameters, $L_{0.1}$ shows very high correlation, significant at the 0.1% level. The total L_{eq} on the site (for all noise) correlates well with train noise annoyance but the L_{eq} for train noise alone normalized over 24 hours is slightly (but not significantly) higher. The logarithm of the fractional train noise duration also correlates well with train noise annoyance.

To further investigate the situation a multiplelinear regression analysis was performed using $L_{0.1}$ and $\log \frac{T}{24}$ as independant variables.

The regression line obtained had the equation

$$\text{Percentage annoyed} = -49 + 1.7 \left[L_{0.1} + 10 \log \frac{T}{24}\right] \quad (1)$$

with a corresponding correlation coefficient of 0.78 and a standard error of estimate of 17%. This regression line with the data points is shown plotted in Figure 1 together with the plus and minus one standard error of estimate lines. It is interesting to see that the $10 \log \frac{T}{24}$ term in equation 1 is an energy type level/time trade off relationship thus supporting the applicability of L_{eq} for train noise assessment. Schultz (7) suggests a very similar rating scale of $L_{peak} + 10 \log \frac{T}{24}$.

For completeness a single regression analysis was performed with the train noise L_{eq} normalized to a 24 hour duration as independant variable. The regression line obtained had the equation-

$$\text{Percentage annoyed} = -22 + 1.5 \, L_{eq} \quad (2)$$

the correlation coefficient being again 0.72 and the standard error of estimate 18%. This regression line is also shown along with the data points and plus and minus one standard error of estimate lines in Figure 2. As the correlation coefficients of L_{eq} and $\left[L_{0.1} + 10 \log \frac{24}{T}\right]$ are not significantly different then either rating scale could be considered to be equally as appropriate for the assessment of train noise annoyance.

6. <u>CONCLUSIONS</u>

The percentage of people annoyed by trains (obtained from a sociological survey) was correlated against various statistical parameters of noise (obtained by noise monitoring and analysis) for 17 sites. Approximately ten people were interviewed per site and noise recordings were made to capture short duration intermittent and continuous events.

The best correlators with train noise annoyance were $L_{0.1}$, L_{eq} for trains only normalized to 24 hours and $\log \frac{T}{24}$ were T is the audible train duration in hours per 24 hours. A multiple regression analysis was formed using $L_{0.1}$ and $\log \frac{T}{24}$ as independant variables and the following regression line obtained:

$$\text{Percentage annoyed} = -49 + 1.7 \left[L_{0.1} + 10 \log \frac{T}{24}\right] (\pm 17) \quad (1)$$

The term $10 \log \frac{T}{24}$ indicates the applicability of an energy type time/level trade off relationship for train noise. The correlation coefficient obtained was 0.78, which is higher than that obtained for the train L_{eq}, but not significantly different The regression line for the train noise L_{eq}, (normalized over 24 hours) is as follows:

$$\text{Percentage annoyed} = -22 + 1.5 \, L_{eq} \, (\pm 18) \tag{2}$$

Either rating scale is considered equally applicable for the assessment of train noise annoyance.

The lower level statistical parameters L_{90}, L_{50}, L_{10} were found not to be significantly correlated with train noise annoyance At first sight this is an expected conclusion as the train noise is a short duration event. However, as no significant negative correlation was obtained it would appear that the background noise levels do not significantly affect the assessment of train noise annoyance.
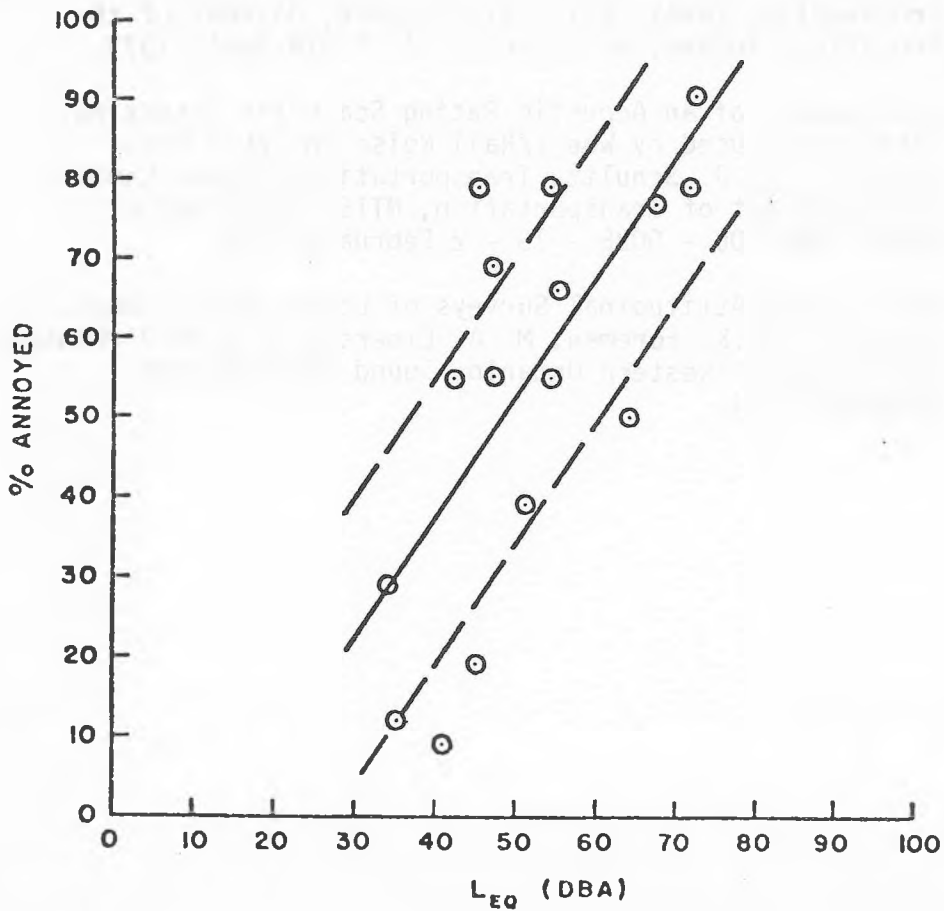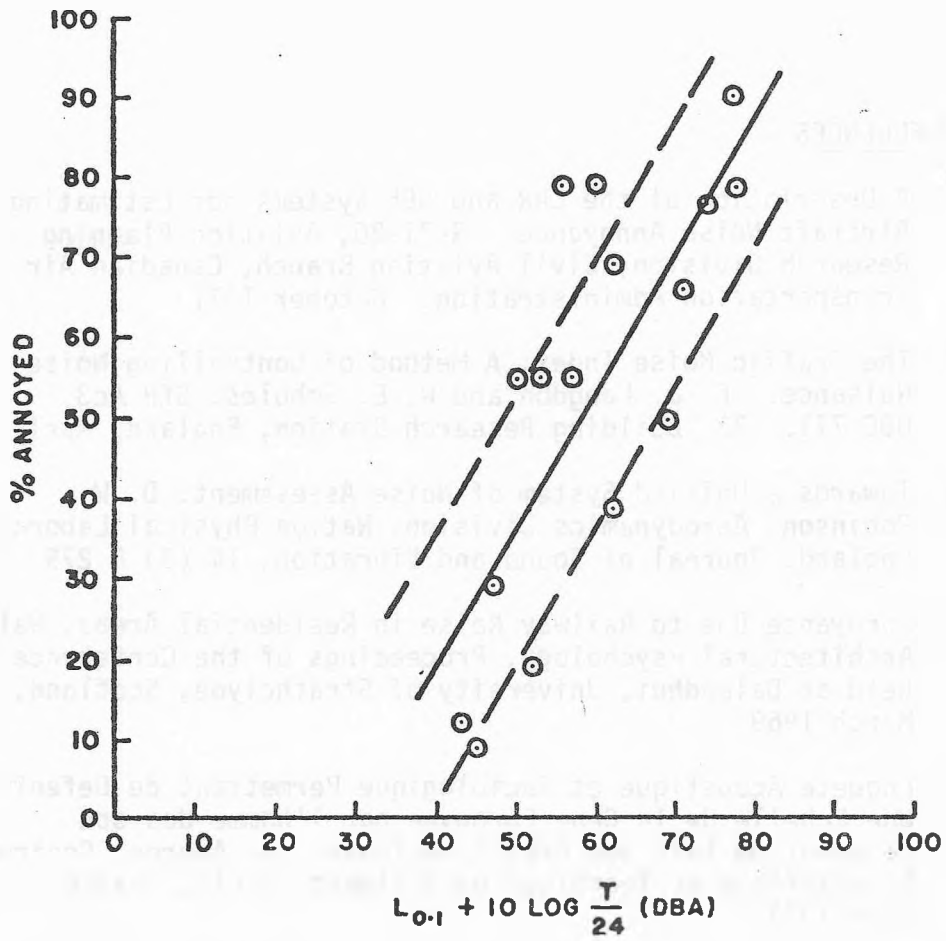
FIG 2

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