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ABSTRACT

A study consisting of acoustic measurements at fourteen sites in the London area and 1200 interviews dealing with the effects of the noise conditions prevailing at each of these sites has been carried out with the object of developing acceptability criteria for traffic noise from roads in residential areas. Dissatisfaction with the noise conditions, as expressed by residents at each of these sites, was related to sound levels in such a way that it was possible to predict the mediar level of dissatisfaction at each site by the use of a measure taking into account the mean sound levels exceeded for 90 per cent and 10 per cent of the sampling periods through a whole day. Individual dissatisfaction scores correlated poorly with physical measures. This finding is believed to be the result of wide individual differences in susceptibility to and experience of noise, as well as in patterns of living likely to be disturbed by noise. (TC)

APRIL 1968

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SUBJECTIVE RESPONSE TO ROAD TRAFFIC NOISE

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A study consisting of acoustic measurements at fourteen sites in the London area, and 1200 interviews dealing with the effects of the noise conditions prevailing at each of these sites has been carried out with the object of developing acceptability criteria for traffic noise from roads in residential areas.

Dissatisfaction with the noise conditions, as expressed by residents at each of these sites, was related to sound levels in such a way that it was possible to predict the mediar level of dissatisfaction at each site by the use of a measure taking into account the mean sound levels exceeded for 90% and 10% of the sampling periods through a whole day, which it is proposed to call the Traffic Noise Index (TNI). Predictions made on the basis of either 10% or 90% levels alone were considerably less accurate than those made on the basis of the combined measure.

Individual dissatisfaction scores correlated poorly with physical measures. This finding is believed to be the result of wide individual differences in susceptibility to and experience of noise, as well as in patterns of living likely to be disturbed by noise. Attempts to allow for these factors were unsuccessful. Disturbance of various activities was shown to be related to noise levels and the increasing extent of this effect with worsening of noise conditions was used to validate the scale of dissatisfaction.

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SUBJECTIVE RESPONSE TO ROAD TRAFFIC NOISE

by I.D. Griffiths and F.J. Langdon

INTRODUCTION

Chapman (1948) carried out a study of noise in British homes and found that of the noises which originated externally, the most frequently reported were the noise of road traffic and the noise of domestic animals. Since 1943 (when the fieldwork for this survey was carried out) the amount of traffic on the roads has increased very considerably and so, presumably, have noise levels. Twenty years later, a BRS Digest (1963) suggested that 'intrusive noise is most widespread in cities and recent surveys have shown that traffic noise is frequently the predominant source'. It has been shown that noise may affect efficiency in a working situation, directly by impairing the performance of tasks (Broadbent, 1958) and indirectly by inhibiting the formation of working groups (Stemerding-Bartens 1960). At extremely high sustained levels of noise, permanent hearing loss may be caused (Acton, 1967). Prior to McKenneil's study of aircraft noise around London Airport (1963), a problem in many ways analogous to the problem of road traffic noise, studies of the effects of aircraft noise concentrated mainly on observable variables (for example, the community reaction studies of Stevens, Rosenblith and Bolt, 1955; Borsky, 1961). Study of wholly subjective response has thus been relatively slight in volume since the work of Beranek (1956), although Langdon (1965) and Keighley (1966) have studied the acceptability of office noise and Keighley has constructed criteria on the basis of acceptability.

Measurements of sound levels produced by road traffic are commonly described in the literature. The Greater London Council have sponsored measurements alongside an elevated urban motorway (Stephenson and Vulkan, 1966), while Lamure and Auzou (1964, 1966) have recorded noise beside motorways, measured the traffic volume and assessed its composition in their studies of sound propagation. Measurement of traffic noise has a long history in Germany (Meister, 1956, 1964). Purkis (1964) has measured noise levels at 500 points in London, and observes that noise from traffic predominates and causes disturbance to people indoors. Most of these workers suggest that traffic noise is likely to increase rather than decrease in the future, and that the problem is one that must be faced in town-planning.

The solutions proposed, apart from acoustic treatment of buildings likely to be exposed to high sound levels (which are dealt with in the BRS Digest already referred to), resolve into (a) the separation of traffic from residential areas, (b) shielding buildings from roads by cuttings, barriers or embankments and, occasionally (c) reducing the noise emitted by vehicles. Reichow (1963) and Meister (1964) suggest solutions of the first and second varieties.

The application of any of these modes of solution to the traffic noise problem presupposes that it is known at what point the problem would be solved. The noise levels created by roads are known, the methods of reducing these noise levels are also (to some extent) known, but the levels to which they should be reduced remain unknown. Standards are in fact frequently suggested, often in seemingly precise terms, differentiating between one type of building and another. Standards based on expert advice may be found, for example, in the Final Report of the Committee on the Problem of Noise (1963). However, the basis for these standards, which would presumably be the feelings of people about noise, is not clearly stated. In the study of aircraft noise annoyance around London Airport, McKennell (op. cit.) has established a relationship between a physical measure, the Noise and Number Index, and levels of annoyance. Standards based upon these measures have been adopted and applied. A similarly well-founded standard is needed for traffic noise though it has not yet been established. For reasons which appear to be largely concerned with sampling methods, McKennell and Hunt (1966) were unable to demonstrate a relationship between annoyance and sound levels in the social survey which accompanied the London Noise Survey, although Lamure and Bacelon (1967) have expressed a relation between the level of traffic noise and annoyance, based on calculated noise levels in place of measured values. The present study was therefore undertaken to establish criteria in terms of the extent of dissatisfaction caused by different levels of noise, by relating interview data to the results of acoustic measurements.

PRELIMINARY INVESTIGATION

Before the large scale study was begun, an exploratory survey was carried out to clarify the techniques of investigation to be used. A questionnaire was designed, the content of which was largely based on the information gathered in twenty non-directive interviews in areas with high levels of traffic noise. This questionnaire was then administered to a sample of 100 residents at each of two locations, chosen because of their widely different traffic volumes. A scaling technique described by Edwards and Kilpatrick (1948) was employed to eliminate items which failed either to discriminate between the two samples or to form part of a scale. The remaining items formed the basis of the final questionnaire.

Acoustic measurements were also made at a number of houses at each site, for a total of 24 hours per site at a sampling rate of 300 sec/h. Analysis showed that it was possible to reduce these figures without appreciable loss of accuracy. The results of this exploratory study are occasionally referred to in this paper for purposes of comparison. Some of them are briefly presented in Table 3, but have not been used in any of the calculations described.

METHODS OF SAMPLING

The study involved the sampling of sites, of their residents, of attitudes and opinions and of sound levels: the methods applicable to each of these are described below. Although anticipating the presentation of results, it has seemed convenient in this section of the paper to dispose of several variables which investigation showed to be unimportant.

(a) Sites

Ideally, sample design would have been based upon sound levels, but because of the absence of information about the distribution of such levels and about methods of assessing probable sound levels from short samples, the alternative of sampling on the basis of another measure fairly closely related to sound level, namely traffic volume, was adopted. The programme of measurement and interview was carried out at twelve sites in the North-west London area. Several short traffic counts were made at each site and scaled up to yield mean daily flows which were compared with a frequency distribution of such flows through Great Britain made by the Road Research Laboratory (p. 42, 'Sample Survey of Roads and Traffic of Great Britain', 1962). Sites were chosen in such a way as to be proportionally representative of the frequencies of such traffic flows in Great Britain.

In selecting sites the following features were sought:

they should not be subjected to noise from major sources other than road traffic noise: one site considered was found to receive fifty low overflights by aircraft per day and on this account removed from the sample;

the roads should be straight and level, without such features as controlled intersections or roundabouts which disturb traffic flow and sound pressure levels;

some sites should be alongside dual carriageways, the remainder beside single carriageways;

housing should be two-storey, three or four bedrooms either semi-detached or in short terraces, parallel to the carriageway and within 50 yd (45 m) of it;

housing should be of similar age and construction to allow the assumption of similar sound insulation values.

It is simple to comply with any one of these criteria but more difficult to meet them in combination. In the event, the required features were largely obtained; distances from the façade of the housing to the kerbside varied between 28 and 120 ft (8 - 36 m), for example, although one site was very near a roundabout, and another one contained traffic lights. The small variations from the requirements have little effect on the relations observed, and may increase the extent to which the results are generalizable.

(b) Site populations

It was felt that the deliberate selection of sites in suburban areas consisting of similar housing types would tend to limit the range of social class in the total sample, and this would make impossible the analysis of any differences between social classes, or between owner-occupiers and tenants, in for example susceptibility to noise. Accordingly, two of the sites chosen were local authority housing projects, the interview results of which could be compared with those of the privately developed sites with similar noise levels. No such differences were found in the analysis. It is not intended to give detailed breakdowns of the populations in terms of age, sex, length of residence or any of the other classificatory data collected, since internal tests showed that these made no difference to levels of dissatisfaction, with a single exception; namely, that respondents of less than six months' residence were more satisfied with the noise levels than respondents who had been at the same site longer.

For the purposes of interview, as many respondents were contacted as could be reached within three call-backs by the interviewers, to a total of 1000 respondents. Heads of households and their wives were interviewed in approximately equal numbers. The overall sampling fraction (i.e., the total number of interviews conducted, divided by the total number of households at all sites) was 57%, and the fractions at sites varied from 40% to 63%.

(c) Sound levels

Measurements were made of external rather than internal sound levels because it was thought that householders would not want a microphone in one of their rooms, and noises arising internally could contaminate recorded levels. Since the buildings at which measurements were made were of similar type and construction (and therefore insulation values), no real disadvantage arises from external measurement.

Traffic noise levels fluctuate considerably with time, and on this account their measurement requires a statistical approach. The assessment of noise levels from single short periods of time on site is thus not feasible if accurate knowledge of average conditions is required. Arrangements had therefore to be made for the noise to be recorded so that the necessary statistical measurement of the levels could be made in the laboratory.

A tape recorder was installed in an upstairs room of one house at each of the sites and connected to a calibrated microphone on the outside of the wall facing the road. This outside microphone was mounted one metre from the wall in front of a window at first-floor level. Recordings were made automatically for 100 seconds in every hour of one complete period of 24 hours. For analysis, the tapes were later replayed through an 'A' weighting network onto a level recorder to which was connected a statistical distribution analyser. This method provided information on the percentages of each sampling period during which predetermined sound levels in dBA were exceeded, from which it was possible to calculate the sound levels (SLs) which were exceeded for 10%, 50% and 90% of each sampling period. Mean values exceeded for these percentages of the time for the whole day were calculated, and these provided the basis upon which the relations with the survey data were explored.

(d) Attitudes and opinions

The interview questionnaire consisted of:

(a) Seven scales concerning various sorts of disturbance which might be expected to result from noise, constructed empirically by the Scale Discrimination Technique (Edwards and Kilpatrick, op. cit.) from statements made in free interviews.

(b) A seven-point scale of dissatisfaction with the acoustic environment of which only the end points were named:

Definitely satisfactory - (1) (2) (3) (4) (5) (6) (7) - Definitely unsatisfactory

Respondents were requested to show what they thought of the traffic noise conditions where they lived by placing a tick along the scale.

(c) Twelve questions used by Lamure and Bacelon (1967) in a study of nuisance caused by noise from motorways. These concerned the way rooms in the house were used, sleep disturbance in adults and children, preferred siting of the house in relation to the road, and possible seasonal or meteorological effects on the perceived noisiness of traffic.

(d) A checklist of possible sources of noise nuisance, upon which respondents could indicate which of the sources they found disturbing.

(e) A scale of susceptibility to noise nuisance (Keighley 1966).

(f) Questions for classification purposes about the age, sex, occupation, length of residence at the present address, and family structure of each household.

Parts (a), (b), (c), (d) and (e) were self-administered, the respondent being allowed to record his answers on the questionnaire himself; information for other parts of the questionnaire was gathered and recorded by the interviewer. The seven scales which formed part (a), although they gave in some cases statistically significant relationships with sound level measures, were not on the whole successful, and these results are not discussed here. Interviewing was carried out by a commercial market research agency, using the questionnaire described above which had been designed by the authors.

RESULTS AND DISCUSSION

(a) Distribution of sound levels

In Table 1 the mean sound levels (SLs) and the range of individual SLs for all the sites are shown.

TABLE 1

Means and ranges of SLs for all sites

SL (in dBA) exceeded for:	Mean SL	Highest SL	Lowest SL
10%	69	76	62
50%	61	68	54
90% of the time	54	63	48

It is impossible to assess how representative these figures are of the distribution of traffic noise levels through Great Britain, but it is possible that the quieter sites are least well represented, since all roads surveyed in this study carried through traffic and were on 'bus routes.

(b) Distribution of scores on the dissatisfaction scale

The distribution of individual scores on this scale is not presented separately, although the distribution of median scores by site is to be seen in Table 3. The relationship between the SLs and dissatisfaction are shown graphically in the next section; the horizontal axis of each of these charts bears a transformation from scores to percentile values. A percentile simply indicates the percentage of the population of individuals under study which has scored a similar or lower score.

Since the dissatisfaction scale achieves only an ordinal level of measurement, rank-order correlations are in the strictest sense the only valid methods of correlation, and these would not allow the calculation of regression formulae. Nevertheless, while the scale does not reach the interval level of measurement, it does yield an approximately normal distribution of scores and it was therefore decided to apply the product-moment correlation which is used for similar reasons in, for example, correlations of IQs and exam results. Where accurate prediction of numerical values is not essential, the Spearman rank-order coefficient has been used.

(c) Sound levels and dissatisfaction scores

As a first step, 10% SLs were correlated with dissatisfaction scores, which yielded a coefficient of 0.51. This did not permit accurate predictions of dissatisfaction averages from sound level. Similar correlations with 50% and 90% levels were also computed. The respondents showed a general preference for the midpoint of the scale (the percentage selecting this was on average 23) so that medians of dissatisfaction did not vary as greatly as is desirable for a good correlation coefficient to be obtained. The percentage of respondents selecting this 'don't know' category did not vary systematically with SL, and when these responses were eliminated, the correlation coefficients were improved. This can be seen in Table 2.

It was thought that a better correlation would result from taking into account more than one measure of noise level. In particular it was thought that the 10% and 90% mean levels might be combined to give a better correlation, since the resulting parameter would be related to variability in noise level. To test this, a multiple correlation of these levels with median dissatisfaction was carried out. It was found that highly significant correlations resulted from the comparison of median dissatisfaction with the mean 10% level minus 0.75 of the mean 90% level (Table 2, where the new parameter is called TNI). This may be rewritten: (mean 10% level - mean 90% level) + 0.25 x mean 90% level. The parameter thus includes the range of the 'noise climate' (as defined in the Wilson Report, op. cit.) and a weighted contribution from the background level. To e ure that the values of the parameter will be free from fractions, it is convenient multiply the expression by 4. Following the example of the Noise and Number Index (McKennell, op. cit.), a constant of 30 may be subtracted to yield more convenient numbers. Thus, the practical version of the e pression is:

4 (mean 10% level - mean 90% level) + mean 90% level - 30.

This measure is called the Traffic Noise Index (TNI).

TABLE 2

Pearson correlation coefficients between Median Dissatisfaction Scores and SLs

	SL 10%	SL 50%	SL 90%	TNI	
Median	.51*	.35	.19	.81**	including midpoint
Dissatisfaction	.60*	.45	.26	.88**	excluding midpoint

$*p < .05$: $**p < .001$
n = 11 significance one-tailed

Figures 1, 2, 3 and 4 show the relations between these measures and median dissatisfaction scores, with calculated regression lines and 5% confidence limits.

The superiority of the 10% level to other simple level measurements as a predictor of dissatisfaction is shown, as is the superiority of TNI to all three. As some index of the reliability of the measures, results from pilot-survey sites obtained some six months earlier are also shown. Table 3 is a summary of SLs and dissatisfaction scores at all sites and also gives approximate daily traffic volumes.

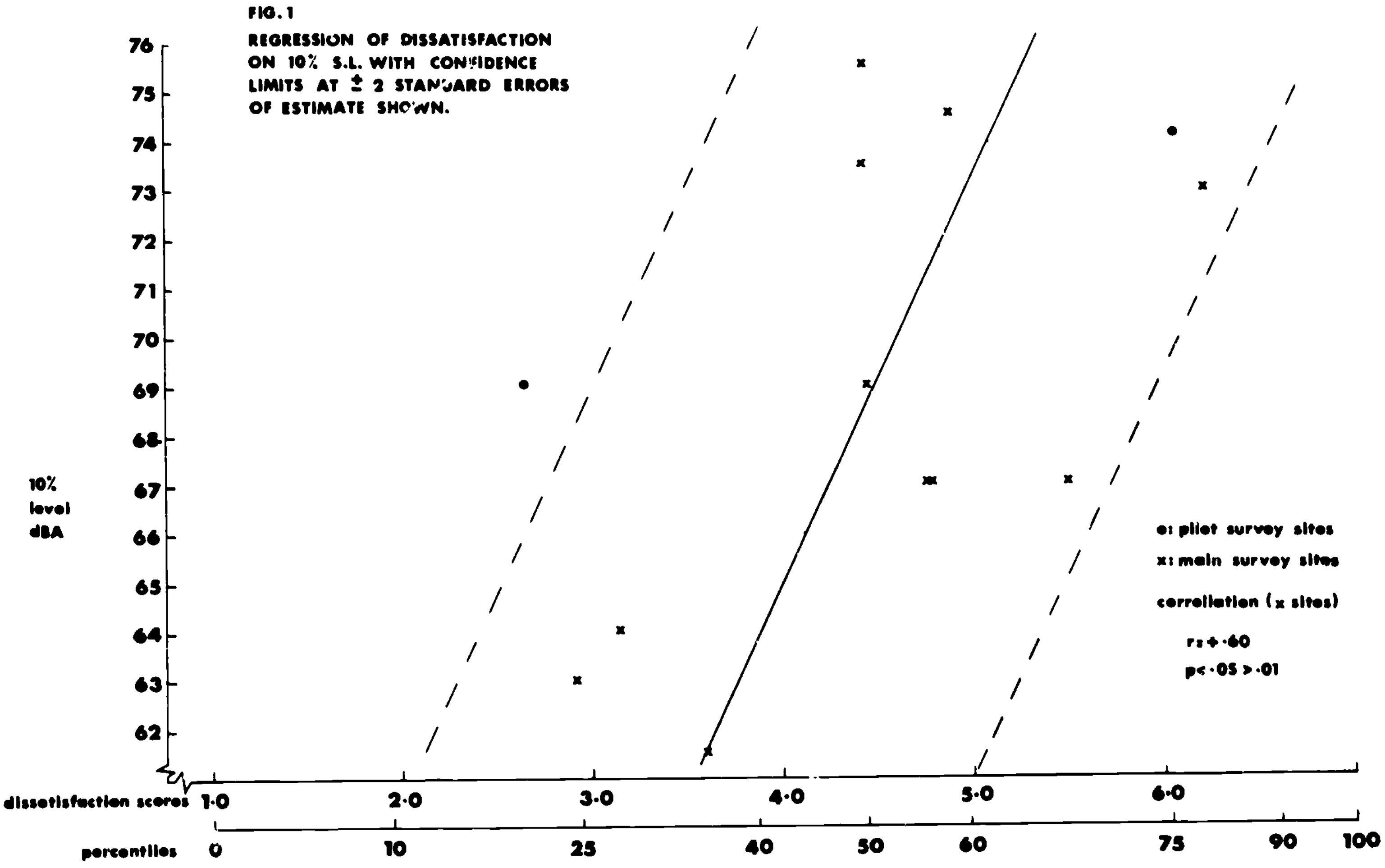


FIG. 1
REGRESSION OF DISSATISFACTION ON 10% S.L. WITH CONFIDENCE LIMITS AT ± 2 STANDARD ERRORS OF ESTIMATE SHOWN.
10% level dBA
o: pilot survey sites
x: main survey sites
correllation (x sites)
r = +·60
p<·05 >·01
dissatisfaction scores
percentiles

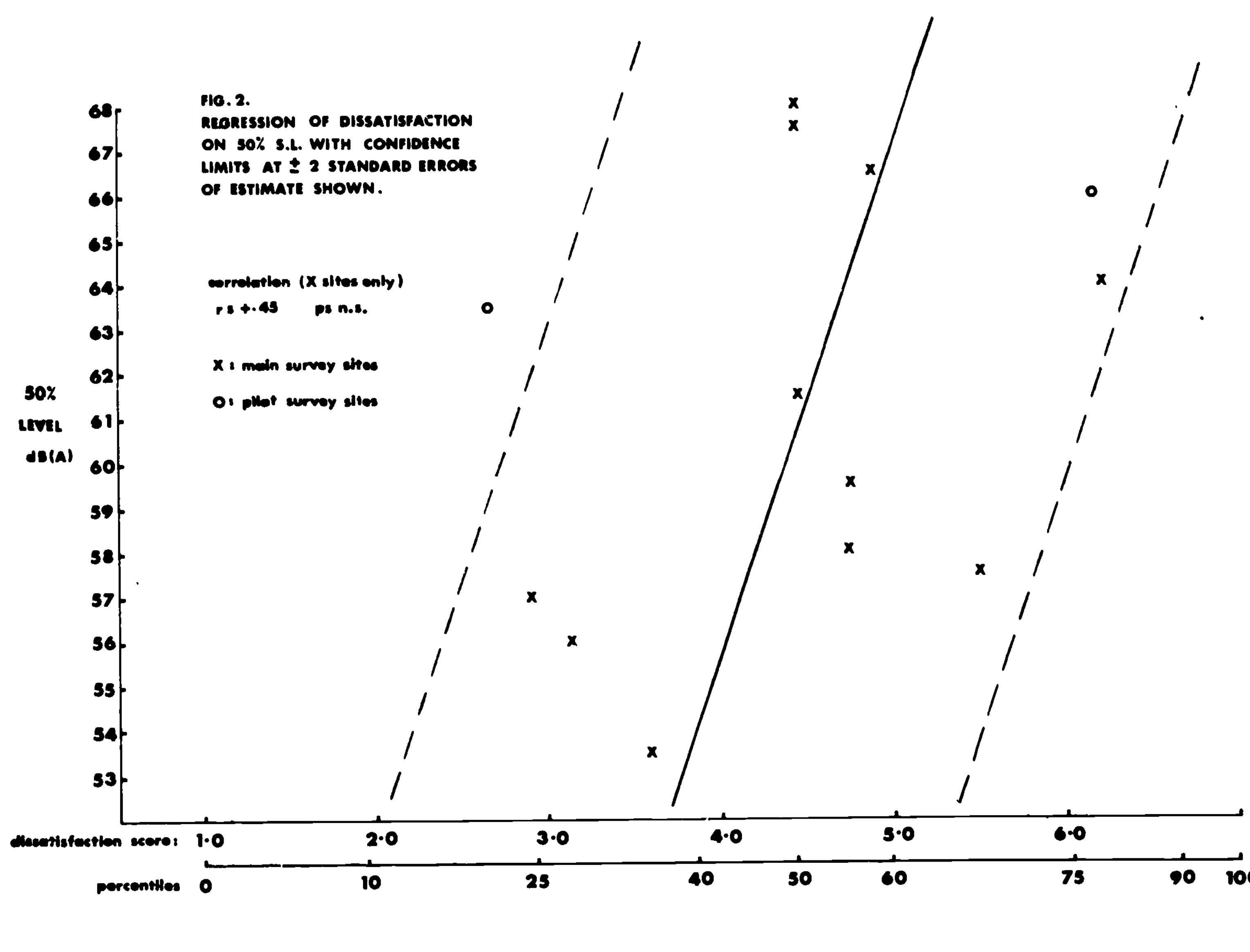


FIG. 2.
REGRESSION OF DISSATISFACTION ON 50% S.L. WITH CONFIDENCE LIMITS AT ± 2 STANDARD ERRORS OF ESTIMATE SHOWN.
correlation (X sites only)
r = +·45 p = n.s.
X : main survey sites
O : pilot survey sites
50% LEVEL dB(A)
dissatisfaction score:
percentiles

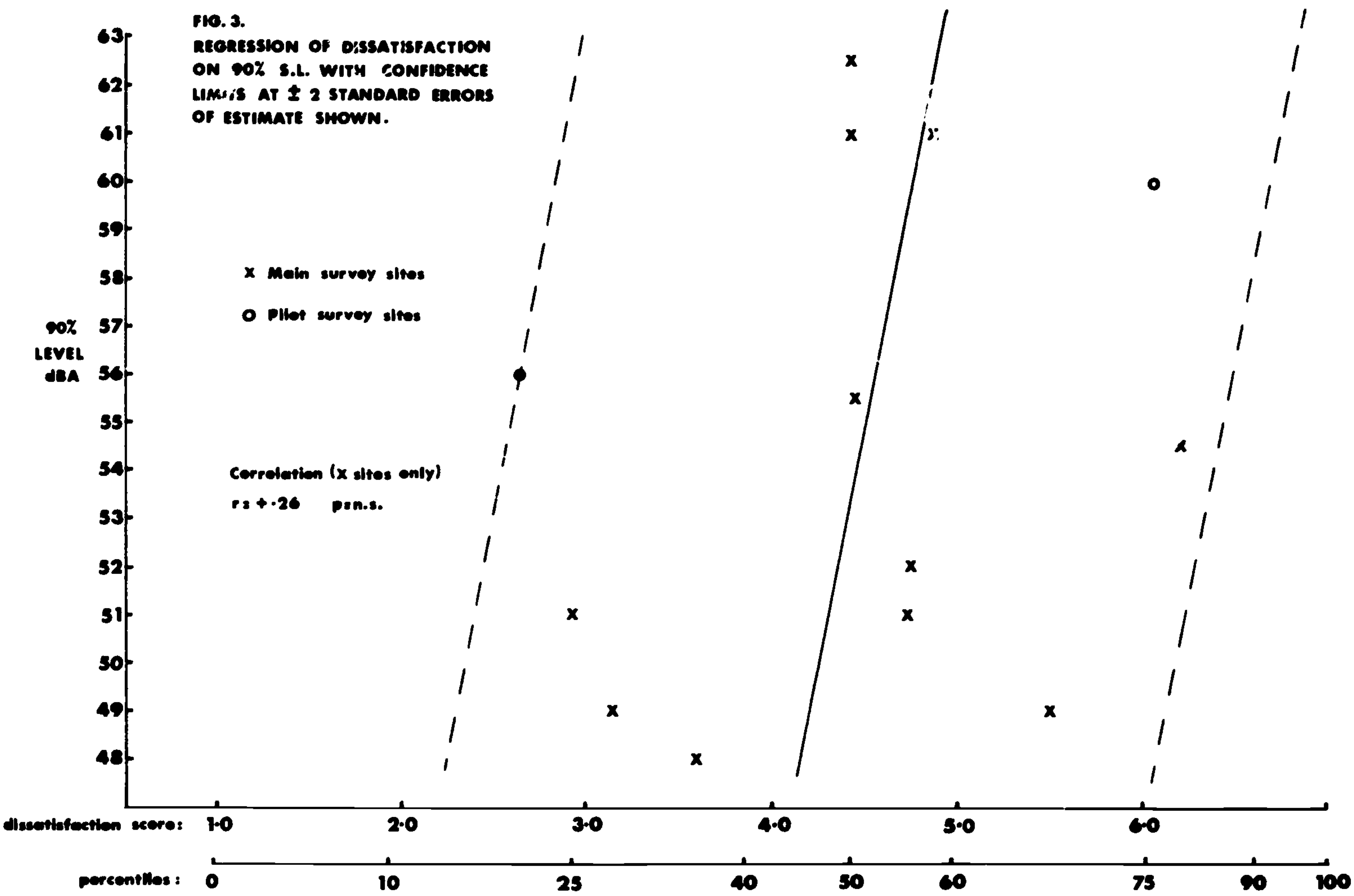


FIG. 3. REGRESSION OF DISSATISFACTION ON 90% S.L. WITH CONFIDENCE LIMITS AT ± 2 STANDARD ERRORS OF ESTIMATE SHOWN.

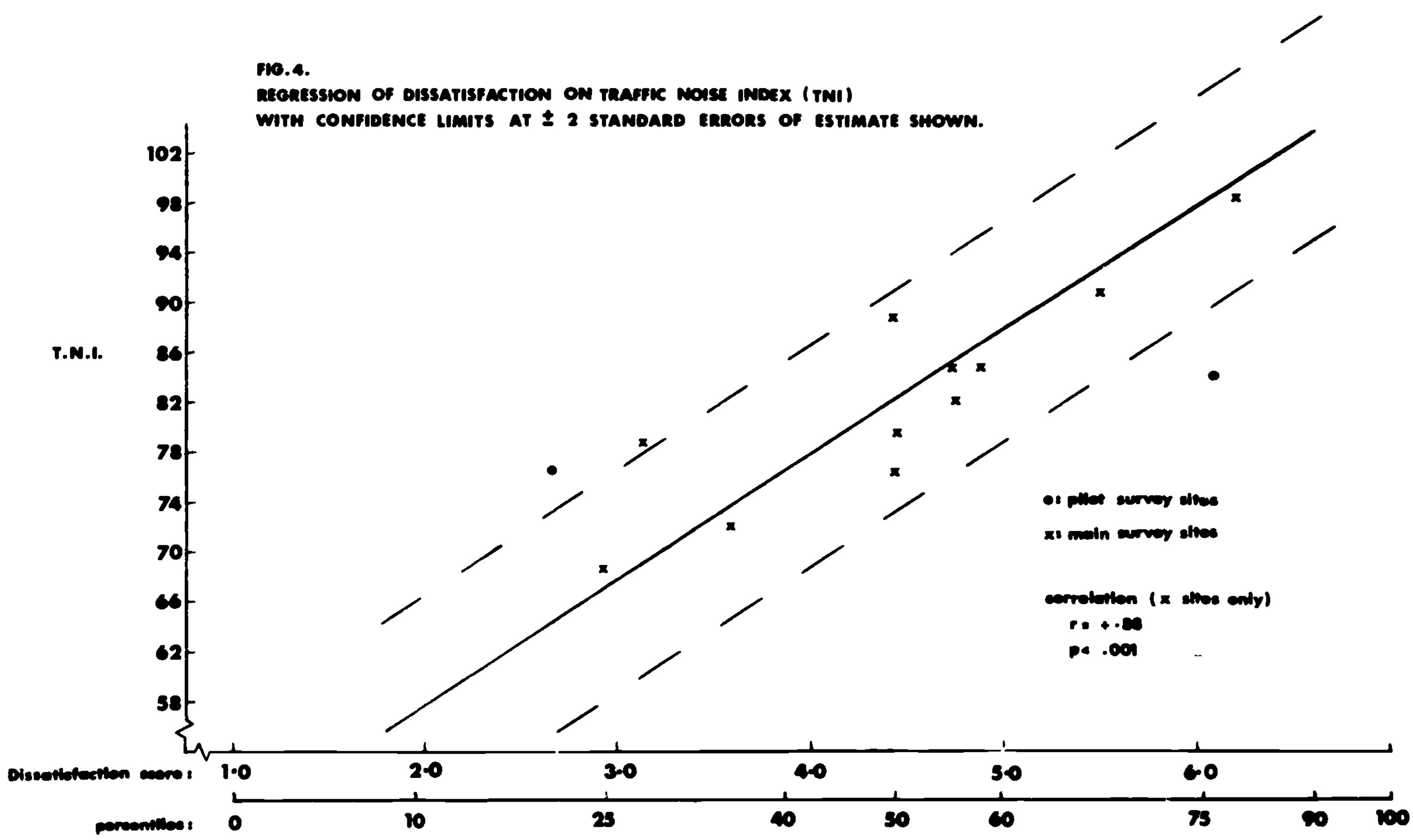


FIG. 4. REGRESSION OF DISSATISFACTION ON TRAFFIC NOISE INDEX (TNI) WITH CONFIDENCE LIMITS AT ± 2 STANDARD ERRORS OF ESTIMATE SHOWN.

TABLE 3

Mean sound levels (in dBA).
Dissatisfaction scores and daily traffic flow by site

Site	Number Interviewed	Mean Sound Level (dBA) 10%	50%	90%	Traffic Noise Index	Median Dissatisfaction score	No. of People Described by Median	Mean Daily* Traffic Flow Range (Nov.-Dec. Figs.)
Main Survey								
1	93	73	64	54.5	98.5	6.21	65	5
2	50	63	57	51	69	2.91	44	3
3	97	61.5	53.5	48	72	3.58	63	1
4	80	75.5	68	61	89	4.43	68	4
5	79	73.5	67.5	62.5	76.5	4.43	60	7
6	140	67	58	51	85	4.74	126	3
7	65	67	57.5	49	91	5.5	50	2
8	76	67	59.5	52	82	4.75	64	3
9	71	69	61.5	55.5	80.5	4.45	46	4
10	68	64	56	49	79	3.13	62	2
11	74	74.5	66.5	61	85	4.88	60	6
Pilot Survey								
12	97	69	63.5	56	77	2.63	72	4+
13	101	74	66	60	84	6.08	85	7+

\+ Figures for 1962 supplied by the GLC

* (1) 0-4000 (2) 4001-8000 (3) 8001-12 000 (4) 12 001-20 000 (5) 20 001-30 000 (6) 30 001-40 000 (7) 40 001 + (vehicles/day)

It has been suggested by continental workers (e.g. Lang, 1965) that the equivalent sound level (äquivalenter Dauerstörpegel), or $\bar{Q}$ value, a method of weighting sound levels in dBA for their frequency of occurrence, should be the basis for any annoyance criteria for traffic noise. The $\bar{Q}$ value is given by the formula:

$$\bar{Q} = K \log \frac{1}{100} \sum 10^{\frac{Q_i}{K}} f_i$$

where K is an empirically determined constant;

Q_i is the median sound-level for the 5 dBA interval i;

and f_i is the percentage of sound levels falling within interval i.

Lang (op. cit.) suggests a value of 13.3 for K, and her $\bar{Q}$ values relate to two divisions of the day: Evening and Night (18 - 6 hours), and Day (6 - 18 hours).

Using the acoustic data from the present investigation, it has been possible to calculate $\bar{Q}$ values for the periods referred to above for each survey site, and to correlate these with median dissatisfaction scores. The results of these calculations are shown in Table 4. For comparison, correlations obtained using values of the TNI for the same periods are also shown. It will be seen that for these periods $\bar{Q}$ values cannot be considered to be better predictors of dissatisfaction than values obtained by the TNI method.

TABLE 4

Pearson correlations of $\bar{Q}$ values and TNI for two periods of the day with median dissatisfaction scores.

	Day	Evening and Night
$\bar{Q}$ value	.59*	.57*
TNI	.42	.68*

* $p < .05$, $n = 11$

Since the TNI relates to noise conditions over a period of 24 hours, a comparison was also made on this basis. All $\bar{Q}$ values here were calculated with $K = 10$, which was found to optimize correlations for the 24 hour period. The correlations obtained tend to indicate the superiority in this context of the TNI as a prediction of dissatisfaction. Whereas the coefficient of correlation between the TNI values and median dissatisfaction scores is 0.88 ($p < .001$, $n = 11$), that obtained by the use of $\bar{Q}$ values is 0.64 ($p < .05$, $n = 11$). It is interesting that $\bar{Q}$ is most successful when computed for 24 hours.

It will be noted that Lang (op. cit.) suggests a sampling rate of 10 sec/min, which is six times greater than the rate employed in the present study. However, preliminary noise measurements for this investigation, at a rate three times that used finally, showed only a small improvement in accuracy if the increased rate was used.

In conclusion, it would seem that the equivalent sound level method offers no advantage over the simpler TNI method.

(d) Sensitivity and dissatisfaction

It will be noticed that correlations so far reported refer to median dissatisfaction scores and not to the scores obtained by individual persons. Individual differences in susceptibility to noise and no doubt other factors as well produce a great range of dissatisfaction at any one site. This is presented graphically in Fig. 5 in which the first and third quartiles are shown in addition to medians. The correlation between TNI and individual scores is 0.29 (as compared with 0.88 with medians). This resembles McKennell's result in his London Airport Study (1963) in which the correlation between mean annoyance score and average peak loudness (noise exposure strata) fell from 0.99 to 0.46 when individual scores were used. These smaller correlations are, of course, highly significant on account of the large numbers of observations involved in the computation of their value. The variability of response which reduces the values of correlation coefficients is a common feature of subjective noise studies and is also found in studies in other modalities (for instance, in thermal response, cf Webb 1965), and attempts have been made to construct susceptibility or sensitivity scales, which would make possible the separation of groups of high, low and average sensitivity from the whole population. Correlation coefficients worked on the basis of scores in these sub-groups would be higher than on the basis of the whole population because of the reduction in variability.

With this in view, a scale of tolerance to noise developed by Keighley (op. cit.) and used in the study of noise in offices, was used in the present survey. It was proposed that, in order to be a valid measure of sensitivity to noise, a scale should yield a population of scores which while differentiating the more from the less annoyed at any particular sound level, should produce similar populations of scores at different sound levels (this is the ideal case; it is possible that if sensitive people moved out of areas with high noise levels in sufficient numbers, an inverse relationship between sensitivity and SL might be found). If the population of sensitivity scores at different noise levels were very similar, a correlation between dissatisfaction and sensitivity could not arise in the case of the total population. It is possible to estimate the success of the scale in meeting these criteria by comparing correlation coefficients obtained between sensitivity and satisfaction scores at two randomly selected sites and at all sites combined (Table 5).

TABLE 5

Rank order correlations between dissatisfaction scores and medians of sensitivity scores at two sites and at all sites

	Site A	Site B	All
r_s	0.89	0.94	1.0
$p <$ (one-tailed)	0.05	0.05	0.001

$n = 6$

Since the correlation coefficient, although significant in the individual cases, is also significant in the overall case, the criterion is not met. This, taken with the evidence that sensitivity to noise is positively related to sound level ($r_s = 0.62$, $p < 0.05$), seems to lead to the conclusion that sensitivity as measured here, is substantially dissatisfaction. It may well be that a reasonable operational definition of high sensitivity to noise would be simply the attainment of a dissatisfaction score which is significantly greater than the average for a particular set of noise conditions. In any case the use of measures of central tendency can remove the effects of individual differences in sensitivity and, in the final analysis, standards must take account of highly sensitive as well as average people.

(e) Reported disturbances and sound levels

Table 6 shows the correlations obtained between the incidence of reported disturbances and sound levels, Table 7 the strength of the relationship between median agreement with some statements (extracted from the unsuccessful Guttman scales) and sound level. SLs are expressed as mean levels exceeded for 10% of the time, and also in TNI units.

Most of the correlations in Tables 6 and 7 can only be described as moderate and the correlations with TNI are not better than those with the 10% SL. This is probably due to the size of the individual differences which can be expected to occur both in the importance of the effects which the questions explore and their relative frequencies of occurrence. This is in fact part of the case for the use of generalized scales of dissatisfaction: since people vary greatly in their habitual patterns of living, questions about specific activities are unlikely to apply to sufficiently large proportions of the population to give statistically reliable results.

Despite these provisos, the list of correlates helps to clarify the nature of some of the disturbances caused by traffic noise and its concomitants. Some of the correlations, of course, arise through noise levels being an index of the volume of traffic, which causes nuisances other than noise.

(f) Respondents' opinions of seasonal and meteorological effects on noisiness of traffic

Clear majorities at each site agreed that the direction of the wind made the noise neither worse nor better. There was also agreement about the kind of weather which did affect noisiness: the consensual ranking indicates that noise was considered to be worse in rainy, than in fine weather, followed in rank-order by fog or snow. The coefficient of concordance for this ranking (W) is 0.79, $p < .01$. There was also clear agreement that noise was worse in summer and during the week rather than at weekends.

(g) Particular noises found disturbing at home

While there was considerable agreement from site to site in the proportions selecting particular noises as disturbing (coefficient of concordance, $W = .69$, $p < .001$), absolute frequencies of selection did not seem to vary with any of the physical measures. Thus at all noise levels, the four sources of noise most frequently selected were, in descending order: motor-cycles, trucks and buses, aircraft, sports-cars.

TABLE 6

Rank order correlations between percentage of positive responses and two measures of sound level

Variable correlated with SL	r_s with 10% SL	r_s with TNI
Use of windows:		
%age of sleeping with window open	-.75**	-.33
%age having to close windows when:		
receiving visitors	+.67*	+.5
having meals	+.86**	+.53*
watching TV	+.85**	+.59*
listening to the ratio	+.84**	+.55*
listening to music	+.73**	+.28
%age never having to close windows	-.62*	-.74**
Sleep disturbance:		
Median length of time required for children to get to sleep		
in summer	+.56*	+.19
in winter	-.19	-.38
%age woken by noise stopping	+.47	+.02
%age woken by noise from road	+.05	+.67*

n = 11 : * $p < .05$: ** $p < .01$ (one-tailed)

TABLE 7

Median expressed agreement with some statements correlated with sound levels †

Statement correlated with SL	r_s with 10% SL	r_s with TNI
The value of the house has gone down because of the noise	+.66*	+.64*
The noise gives me headaches	+.02	+.44
If we had the choice we'd move away	+.28	+.72*
The fumes are a nuisance	+.49	+.49
The vibration doesn't do the property any good	+.46	+.59*
We need to paint the house very frequently	+.58*	+.48
We are used to the noise	+.12	+.52

n = 11 : * $p < .05$: ** $p < .01$ (one-tailed)

† Agreement with a statement was expressed on a seven-point scale from 'strongly disagree' to 'strongly agree'.

(h) Locational preferences

No regularity was discernible in preferred distances from the road, nor preference for side or main roads, as related to sound level measures.

VALIDITY AND RELIABILITY OF THE MEASURE OF DISSATISFACTION

All scales of attitude should be of known validity and reliability. Validity is the power of the scale to measure what it is intended to measure; reliability is its power, when applied to comparable populations or re-applied to the same population, to replicate the description of the characteristics of that population.

(a) Validity

The assessment of validity is usually achieved by comparing the measure with the variable it is intended to predict from it. Thus, in validating a test of intelligence, the scores arising from its use would be related to, for example, success in an academic examination. In a case like the present one, where there is no obvious predicted variable, it is usual to have recourse to the concept of construct validity. This involves the construction of a 'theory' about the variables with which the scale should be related, if it is to be meaningful psychologically. A fairly obvious set of variables which would reasonably be expected to vary with dissatisfaction with the acoustic environment are such factors as reported disturbances due to noise, and attitudinal factors such as readiness to move house. If the scale is a valid measure it should correlate significantly with these factors, the magnitude of which may be assessed from the questionnaire responses. Of the questions posed in the present study, it was expected that those concerned with disturbances in room-use, window-use, and sleep, and changes in preferred distance from the road would so vary. Table 8 shows that acceptable validity is achieved. Questions dealing with use of rooms are not covered since none of the intercorrelations were significant. The exact nature of questions other than those concerning room-use may be understood by reference to Table 9. Room-use questions concerned the use of the bed-rooms near the road and the choice of room for meals. Some of the relationships shown in Table 8 are expressed graphically in Fig. 6.

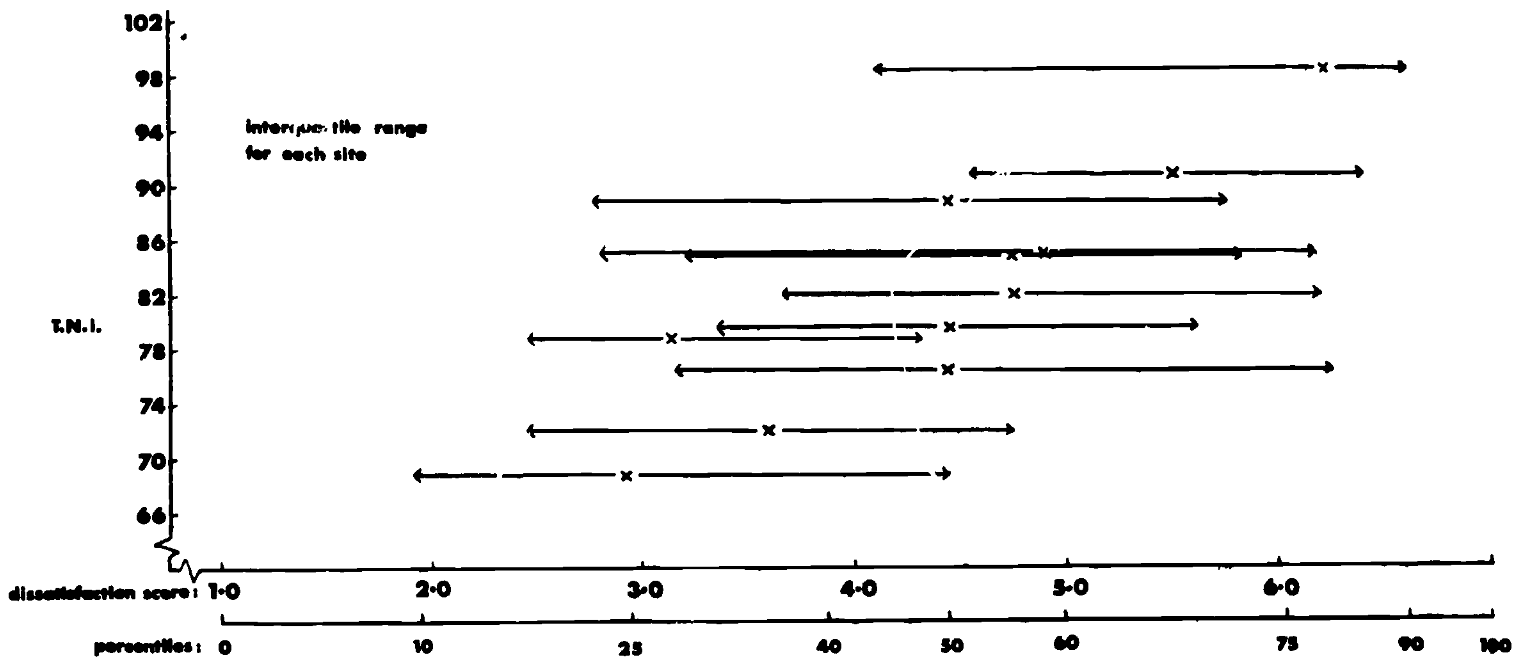
TABLE 8

Rank order correlation between dissatisfaction scores and responses to other questions

	Variable correlated with dissatisfaction	r_s
Use of windows:	%age sleeping with windows open	- .83*
	" sleeping with windows open (summer only)	- .89*
	" having to close windows	
	when receiving visitors	+ .94*
	having meals	+ .83*
	watching TV	+ .94*
	listening to the radio	+ .83*
	listening to music	+ .89*
	" not having to close window at all	- .94*
Sleep disturbance:	%age woken by noise stopping	+ .77
	" woken by noise from road	+ 1.0 **
	Median length of time required for children	
	to get to sleep (in summer)	+ .89*
	(in winter)	+ .43
Preferred distance:	Median preferred distance from road	+ .89*

n = 6 : * $p < .05$: ** $p < .01$ (one-tailed)

FIG. 5.
PLOT OF MEDIAN DISSATISFACTION X TRAFFIC NOISE INDEX
WITH INTERQUARTILE RANGES SHOWN.



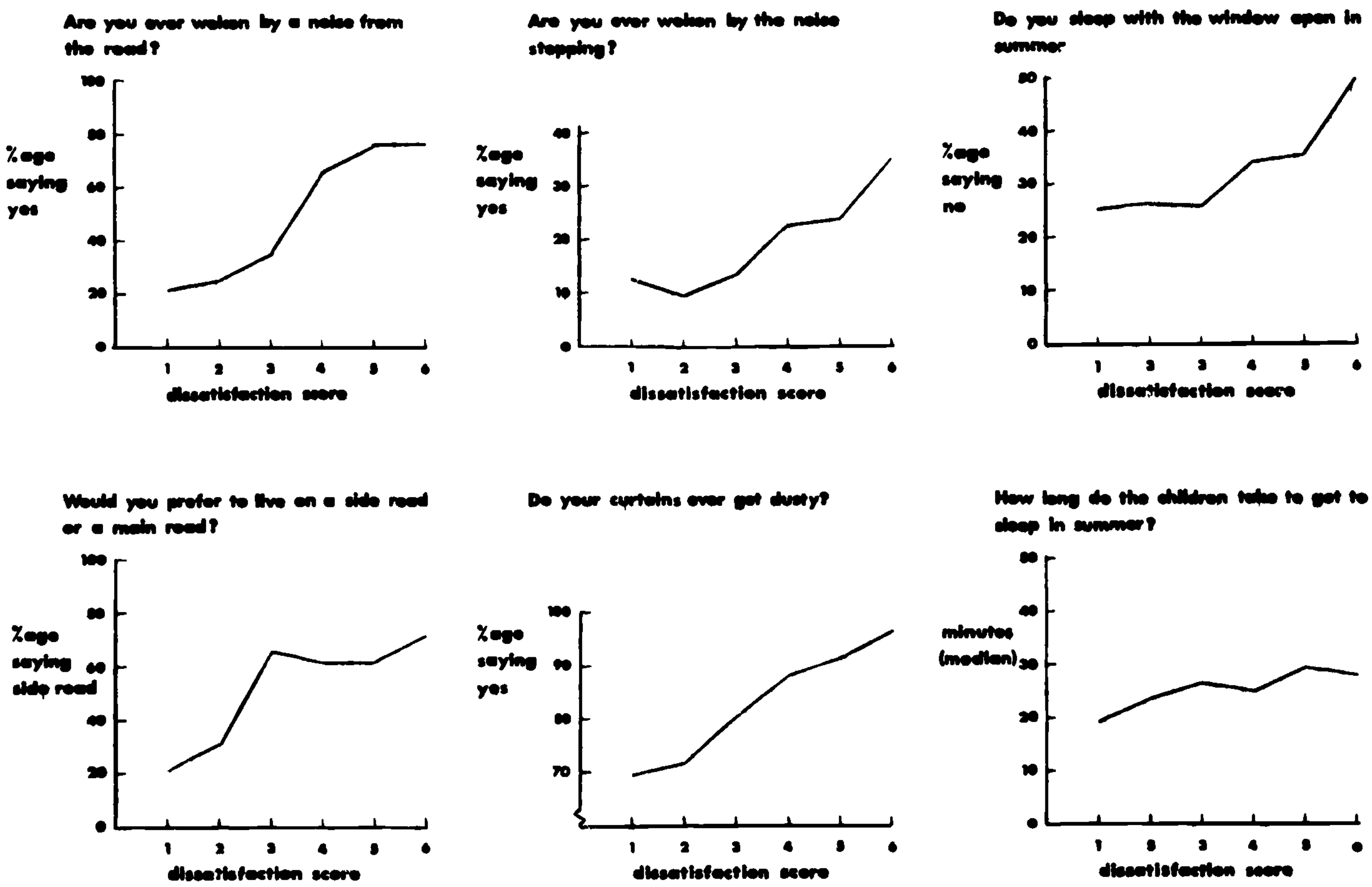


FIG.6. RELATIONSHIP BETWEEN DISSATISFACTION AND REPORTED EXTENT OF SOME DISTURBANCES.

From this table it may be seen that as dissatisfaction increases, the possibility of leaving windows open while sleeping decreases, and the need to close windows while engaging in various domestic activities increases. Also, those who are more dissatisfied report that, as a general trend, their children take longer to go to sleep in the summer. The more dissatisfied also report more disturbance of their own sleep than do the less satisfied, and prefer to live further from the roadside.

Other correlates of dissatisfaction may be seen in Table 9, in which the median agreement to questions extracted from the unsuccessful scales is correlated with dissatisfaction.

TABLE 9

Median agreement with some statements of relevance to dissatisfaction, correlated with dissatisfaction scores

Statement correlated with dissatisfaction	r_s
The value of the house has gone down because of the noise	+ 1.0 **
The noise gives me headaches	+ 0.89*
If we had the chance we'd move away	+ 0.94*
The fumes from the road are a nuisance	+ 0.94*
The vibration doesn't do the property any good	+ 0.94*
We need to paint the house frequently	+ 0.89*
We are used to the noise	+ 0.94*

n = 6 : * $p < .05$: ** $p < .01$ (one-tailed)

It will be noticed that several of these statements relate to nuisances from road traffic other than noise. It would seem possible that the degree of dissatisfaction with traffic noise is not entirely uncontaminated by such factors. To refer again to the advantages of a general scale of dissatisfaction over specific disturbance reports, the comparison of the correlations between these reports and dissatisfaction with those between reports and 10% SL leads to the conclusion that although the reports do not themselves give good correlations with sound levels, they are nevertheless important contributors to dissatisfaction.

(b) Reliability

There are a number of methods of assessing the reliability of a scale, not all of which are suitable in this case. The method of test-retest reliability could not be used because of expense. An alternative form of the scale was not constructed, and a split-half test of reliability (in which the scores attained by use only of the odd items of the scale are compared with those attained using only the even) was not applicable. A modified split-half method was eventually used. Thus it was felt that the hypothesis that under the same acoustic conditions and with the same populations of respondents the scale would yield acceptably similar scores to those in the survey could be tested by the computation of two medians for each site-population (on the basis of randomly-drawn halves of the population), and the correlation of the one set of medians with the other. Strictly, since the scale yields only ordinal data, the Spearman Rank-Order Correlation is applicable; in this case the value of r_s was found to be 0.94 ($p < .001$). However, reliability coefficients are normally expressed in terms of the Pearson product-moment correlation and the value of r in this case was found to be 0.89 ($p < .001$). Since the reliability of each median is reduced by halving the sample-size, the latter coefficient could be corrected for attenuation, in which case its value would increase. Neither of these correlations is concerned with absolute magnitudes, and in fact it was found here that one set of medians was systematically (but slightly) higher than the other. There seems to be no adequate explanation of this, a presumably random phenomenon. In summary, it is reasonable to say that the scale is acceptably reliable.

FURTHER DISCUSSION AND APPLICATION OF TNI

The Traffic Noise Index represents an attempt to describe traffic noise by combining the range of the fluctuation of noise levels (i.e. the range of the noise climate) with the absolute (in this case, 90%) sound level. It is instructive to speculate on the physical parameters which lead to the values of the TNI observed. Both 90% and 10% sound levels (which together specify the range of the noise climate) depend upon traffic volume and distance, but the 10% level is influenced to a greater extent by distance. A simplified approach to the propagation of traffic noise is to regard the 90% level as coming from the whole of the traffic stream and the 10% level from individual noisy vehicles. Because of this the two levels may be expected to suffer different attenuation losses over distance, in such a way that the difference between the levels decreases with distance. This has been borne out in a limited series of measurements which indicates that the 10% level falls off at a rate of about 6 dBA, and the 90% level at 3 dBA for each doubling of the distance from the source. Thus the measure appears to be a combination of the effects of total traffic volume, individual intensity levels and distance from the road.

This index will be seen to have useful implications for noise control and these are briefly indicated below, though it will be realised that the present paper is not the place for an exhaustive discussion. Figure 7 shows that if the TNI and the distance from the road at which the measurement was made are known, it is possible in principle to predict dissatisfaction levels at that distance and at others. For this purpose the distance at which measurements were made, and the co-ordinate of this with the TNI value must be found. From this point a line parallel with the lines of decay of the TNI is projected to intersect the line corresponding to permissible dissatisfaction. A line dropped from this point to the horizontal axis gives the necessary distance, to limit dissatisfaction to a permissible level.

Figure 7 is intended to give some idea of the way in which the TNI may be used in planning and noise control. Although capable of direct practical application in its present form, it is subject to certain limitations. Thus the fall of the TNI with distance is based on currently assumed rates of attenuation for the 10% and 90% levels, and the contours are applicable only to moderate distances from the sound source. Furthermore, the values given relate only to a situation at the façade of a building and would require correction if applied to a free field. Lastly, the predictions are limited to the range of sound levels encountered in the present study.

For the planner, the TNI has a number of advantages. This unit refers to all of the twenty-four hours of the day in a single figure, which obviates the need to satisfy different standards for night and day. It is an external value which allows the protection of the whole environment, not only the interiors of buildings from undesirable levels of traffic noise. It is of interest, too, that high quality traffic engineering which reduces the amount of acceleration and deceleration by smoothing traffic flow, a partial solution to the problem urged by Reichow (op. cit.), would also have the effect of lowering the TNI, as would any reduction of noise levels of individual vehicles. It is worthwhile bearing in mind that measurements made to yield data comparable with 10% SL recommendations will also, with very little more trouble, yield TNI values, to some advantage.

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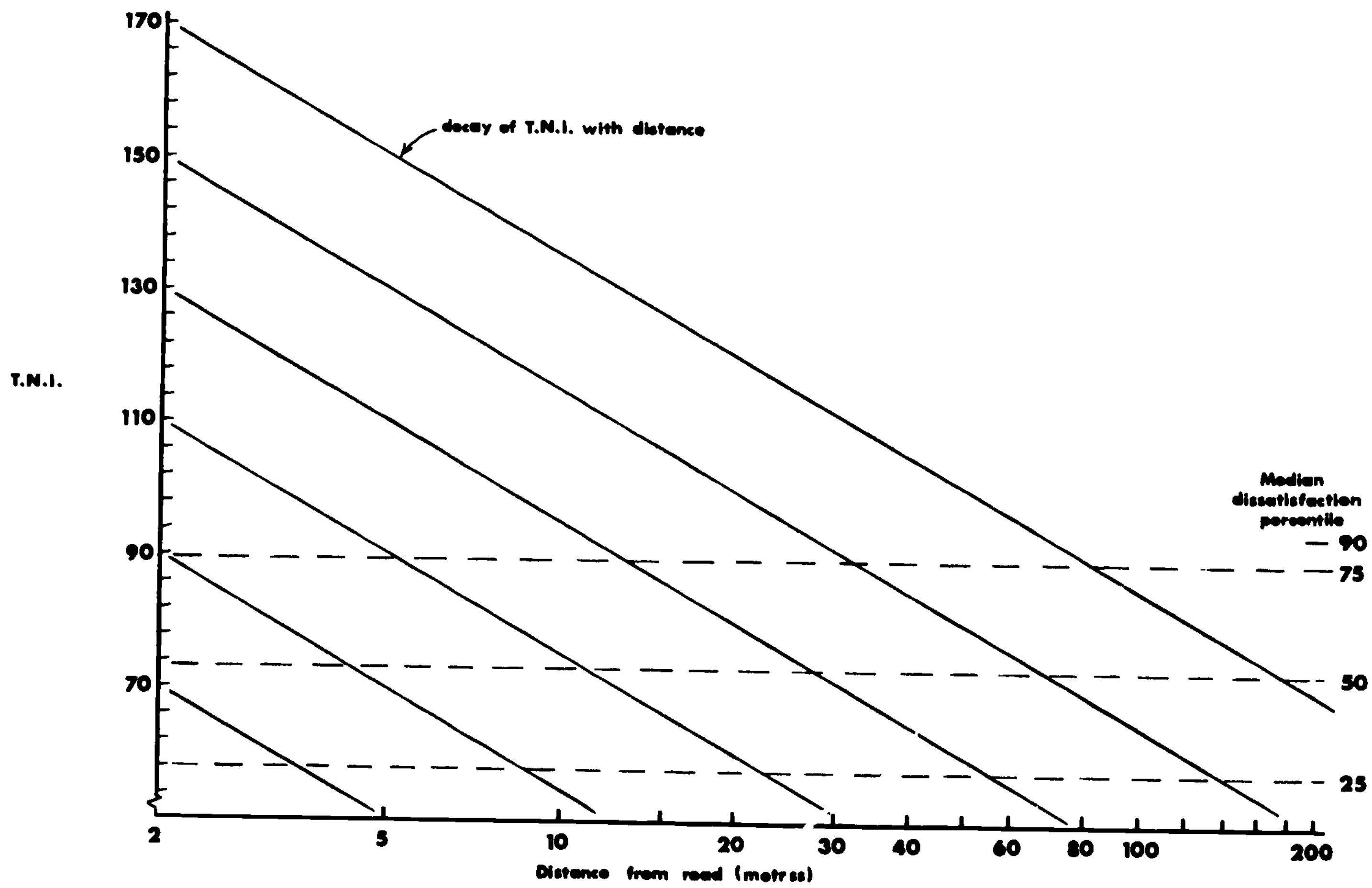

FIG. 7. SUGGESTED FORM OF A CHART TO PREDICT THE MINIMUM ACCEPTABLE DISTANCE FROM THE ROAD FOR VARIOUS LEVELS OF DISSATISFACTION GIVEN ONE MEASUREMENT OF T.N.I. (EXTERNAL) AND DISTANCE.

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