PREDICTING COMMUNITY RESPONSE TO SURFACE TRANSPORTATION NOISE: PRELIMINARY FINDINGS FROM THE HAMILTON-TORONTO URBAN CORRIDOR

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The purpose of this paper is to identify a means for predicting, for residential neighbourhoods, the percentage of the population likely to be disturbed by any given transportation noise environment. The equation to be developed will depend only on those characteristics of the noise environment which can be predicted with the present state of the art. The reason for this is that the most fruitful applications of such an equation are in predicting the impact of possible future actions. For existing situations, it is almost as simple to survey personal reactions as it is to monitor noise levels.

The paper focuses on residential neighbourhood noise resulting primarily from ground transportation systems. This means noise caused by expressways, arterial roads, rail lines, and combinations of these. In an attempt to determine whether reliable predictions can be made without reference to the specific noise source (given that it is a ground transportation source), this paper will report results based on sites representing all of the sources. It is expected that subsequent work will test these general findings on larger, source specific data sets.

The reader may wish to object at this point, that at best this paper will add yet another set of initials to an already extensive list (TNI, NPL, (or L_{NP}), NNI, CNEL, L_{eq}, etc.), or less optimistically, will simply replicate what has already been done. Our aim is not derive a measure of noise, which would have units of, e.g. dBA, but to produce a measure of community reaction to noise, which will have units of percent of population disturbed. Our measure will be based on the physical measures of noise, certainly. However, it goes beyond them to permit a statement of results in terms of total number of people disturbed, so that it is possible to compare more easily a variety of proposed plans. (See Hall and Allen (1) for elaboration of this point.)

In the following sections, we describe work leading to several plausible equations for the proposed measure. The first section briefly describes the data on which the analysis is based. The next section deals with the simple correlations among the several variables, which served as essential starting information for the regression analysis reported in the third section. The final part of the paper briefly compares this work with that on which TNI and NPL are based.

Description of the data base

The data analysed here represent part of that collected during the summer of 1975, with support of the Ontario Ministry of the Environment and the National Research Council. A total of 28 sites were surveyed, in the Hamilton, Burlington, and Mississauga areas. Survey procedures consisted of

(1) identifying a site, based on its characteristics with respect to a particular transportation noise source;

(2) conducting a household interview with a target of roughly 30 interviews per site;

(3) monitoring the noise levels at the site for at least one and preferably three days.

The interviewing was carried out from May 23rd to July 18th, resulting in a total of 837 individual interviews. Due to weather and equipment problems, the monitoring was not so successful, and in fact is still in process. As a result, only 25 monitor days, representing 14 sites, were available for analysis for this paper. Discussion of each of the three survey components is helpful for an understanding of the analysis.

Site selection is critical for this kind of study. Ideally, every housing unit in the site should be exposed to an identical external noise environment, a requirement which has led to poor results in some previous studies (2, 3). This normally means only a small number of units can be included in each site. On the other hand, if the interview data obtained at the site are to have any statistical reliability as representative of response to that noise environment, then the number of interviews at each site should be reasonably large. There will usually be a non-response problem in household interviewing, either because people are not at home, or because they choose not to participate. Hence the site should, for practical reasons, contain at least 50%, and possibly 100% more housing units than one intends to interview.

Fortunately, the types of noise source of interest for this paper are essentially linear, rather than point. This means that it is theoretically possible to satisfy both of the apparently contradictory selection criteria just identified, by taking a single row of housing paralleling a specific source. Problems still arose, however, in finding 50 housing units in such a row. Table 1 identifies the housing and noise environment characteristics for the 14 sites used in this analysis.

The item in the questionnaire on which most of this paper is based is a nine-point rating scale used in response to the question, "How would you rate the overall noise in this neighbourhood?" The nine points of the scale consisted of labels, as follows:

extremely	agreeable
considerably	agreeable
moderately	agreeable
slightly	agreeable
neutral	
slightly	disturbing
moderately	disturbing
considerably	disturbing
extremely	disturbing

This, of course, represents an ordinal scale, and while one can number the scale points, the numbers will contain information only on the order of the responses, not on intervals between them. Consequently, only limited arithmetic operations are valid. This point should be obvious, but has proved in the past to be a stumbling block for similar studies (4).

The fact of ordinal data poses a particular problem given that we wish to aggregate the data at each site, and then to compare findings across sites. Two approaches are possible. The first is to calculate the median response score at each site, which permits rank-order correlations between physical and social data, but not regression analysis. The second is to dichotomize the scale, to disturbed and not disturbed categories, and to determine the percent disturbed at each site (3). This would permit a regression analysis, although it is dubious in that it collapses a meaningful nine-point scale into an artificial two-point scale. In fact, it appears that there are two recognizable types of disturbance response in the data. The advantages gained by allowing legitimate regression analyses outweigh the damage done to the scale however, and tests against two other questions from the survey indicated a high degree of reliability for this approach. Some information has been lost by using it, nevertheless.

All of the monitoring for this study was carried out using a timer-activated analog recording unit, with the timer set to record roughly 10 seconds every 2 1/2 minutes. Although 25 days of monitor information are available, the analysis will be restricted to a single tape per site, or 14 days. The primary reason for this is that we have only one measurement of overall response to the noise at each site. Hence to use all 25 days would mean repeating the same response data for two or three sets of physical data. The effect of this would be to weight those sites for which multiple tapes are available more heavily in the results, for which there is no justification. Fortunately, preliminary analyses of all 25 days indicated a very close correspondence among the several days of record for each single site. Selection, for those sites with more than one monitoring day, was accomplished by deleting Saturdays and Sundays, and selecting randomly if more than one weekday remained. The day of the week for the monitor record used in the analysis is shown for each site in Table 1.

Correlation of physical and social data

Two facts stand out upon inspection of the simple bivariate correlation coefficients. First, the response data correlate strongly with many of the direct measures of noise levels, not simply with one or two. And second, the direct measures of the noise distribution generally give better correlations with the response data than do several of the more involved measures which have been developed in the literature. Table 2 presents the correlations in support of these statements.

Five direct measures of the distribution of noise levels over time were used for this study: L_{90}, L_{75}, L_{50}, L_{25}, and L_{10}. Separate time-varying distributions were calculated for daytime (0700-1900), evening (1900-2300), and night (2300-0700), resulting in a total of 15 direct measures of noise level. Of these, 13 produce correlation coefficients with the response variable which are significant at the .05 level. The correlations for all five measures for the daytime are significant at .001, with the lowest coefficient being r = 0.758, for L_{10}.

The fact that all of the measures correlate highly with the response variable indicates that there is a high degree of correlation among the direct physical measures. While this is not surprising, it is important to keep in mind the fact that any conclusions from this study will necessarily apply only to situations in which the noise measures are so highly correlated.

The other point to be extracted from Table 2 is that the L_i measures in general perform much better than the more complicated measures which have been suggested for assessing the community impact of traffic noise. Because of the significance of this finding, we shall deal with each measure separately.

Two measures of the 'average' noise were used: the arithmetic mean of the dBA readings, μ, and the equivalent sound level, L_{eq}. The mean dBA level did correlate roughly as well as the direct measures, such as L_{50}, but did not improve on them. L_{eq}, on the other hand, did not do so well as the direct measures. Except for the night period, when L_{90} and L_{75} did not produce significant correlations with response, the L_{eq} correlation was lower than any of the direct measures.

Building on L_{eq} and μ are the L_{NP} measure ($L_{eq} + 2.56\ \sigma$) proposed by Robinson (5) and a measure consisting of $\mu + 0.5\ \sigma$, recently proposed by Johnston and Carothers (6) as an improvement on L_{NP}. Our data support the findings of Johnston and Carothers, that $\mu + 0.5\ \sigma$ gives better correlations with response data than does L_{NP}. However, our data also suggest that the σ term makes little if any improvement on the correlation of μ alone.

The remaining measure for road traffic noise is the Traffic Noise Index ($TNI = 4(L_{10} - L_{90}) + L_{90} - 30$) proposed by Griffiths and Langdon (4).

With our data, it is among the weakest correlates for day and evening, and among the best for night. If we attempt to replicate the conditions under which TNI was developed, by using data from only the 8 road traffic sites, and aggregating the three time periods to produce a single 24-hour record, the measure still does not do well. L_{50}, L_{25}, and L_{10} all correlate with the response variable at greater than $r = 0.7$, while TNI correlates at only $r = 0.605$, as opposed to the $r = 0.88$ which Griffiths and Langdon report.

Development of a regression equation to predict disturbance

In attempting to identify a good equation for predicting the percentage of population disturbed, we made use of several criteria, as follows.

1. The independent variables in the equation should not be highly correlated with each other. (Regression analysis assumes they are statistically independent, which would mean zero correlation.)

2. The combination of coefficients (including sign) and variables must make sense, not merely provide a statistically good fit.

3. The variables used in the equation should all be significant at the .05 level in that particular combination.

In order to better understand the available data, partial correlations were calculated for all variables against the response data, while holding each other variable constant. The most striking finding from this was that when the night measures were held constant, the daytime L_{75} had the strongest partial correlation in all but two cases. For those, the daytime L_{50} was strongest. For evening measures held constant, L_{75}, L_{50}, and μ for the daytime were always the top three partial correlates. When the daytime measures were held constant, slightly more variation appeared in the partial correlates, although for the two measures of variation (σ and $L_{10} - L_{90}$), and for L_{eq} the same three measures were again the top correlates.

This means then, that in a stepwise multiple regression equation, no matter what variable is entered first (with the exception of the daytime L_{90}, L_{25}, and L_{10}) one of the measures L_{75}, L_{50}, or μ for daytime will enter next. It seems sensible therefore to focus on those three plus the three exceptions just noted.

Three of these six can be very quickly dealt with. If L_{90}, L_{75}, or L_{50} is placed in a regression equation, no other variable will yield a coefficient significant at the .05 level. Hence by the third criterion listed above, we are limited to single-variable equations. Table 3 contains the relevant data about each equation. The remaining three variables, in addition to the univariate equations, yield two multi-variate equations with significant coefficients, which are also listed in Table 3.

Equation 7, based on L_{25}, does not meet the second criterion, in that the constant term is positive, predicting high annoyance even if there is no noise. Equation 8 also conflicts with the second criterion, because it is difficult to understand why, if average daytime noise levels are held constant, disturbance will decrease as average night-time noise increases. In fact, the second criterion rules out any two-variable equation involving L_{75}, L_{50}, L_{25}, or μ for the daytime. Once one of them is held constant, the partial correlation coefficient is negative for each variable outside that group. The only plausible (in terms of criterion 2) two variable equation involves L_{90} and L_{10} (equation 9). This equation does not meet the first criterion, as L_{10} and L_{90} are closely correlated (0.873).

While it is of course possible to try many other combinations of variables, any plausible ones we have tested have either produced worse results than equations 1 to 6, or have resulted in coefficients which do not fulfill criterion 2. The choice of a predictive equation would appear then to be limited to the first six listed in Table 3. On the basis of both the coefficient of multiple determination and the standard error, the equation based on L_{75} would seem best. If other criteria are important as well, either of the equations based on L_{50} or on μ is almost as good.

Although the equations reported here yield good statistical fits, it is important to be aware of their limitations. For two reasons, they should not be used to estimate changes in the reactions of a single group to a change in the noise environment. They can be used only to estimate responses to reasonably stable noise environments. The primary reason for this limitation is that the data report the reactions of different groups of people in different noise environments, not changes in the reactions of a single group as the noise situation changes. The second reason is an extension of this: once people are accustomed to a particular noise environment, changes in any of several parameters may affect the degree of disturbance they report. These single-variable equations are obviously not sensitive enough to incorporate that.

A second limitation on the equations deals with their predictive reliability, and can be judged by inspecting the statistics reported in Table 3. The value of R for the equations based on L_{75}, L_{50}, and μ ranges from 0.838 to 0.819, indicating that these equations explain only from 67 to 70 percent of the variation in the percent disturbed. In addition, the fact that the standard error of the estimate is between 10.3 and 10.8 means that confidence limits on the prediction need to be fairly broad. The 95% interval, for example, would be the actual estimate $\pm$ 20. While this is not a particularly narrow band, the fact that the actual percent disturbed ranged from 9 to 61 does serve to increase one's confidence in the estimates. Although one should be aware of this limitation, it is reasonable to use one of these equations to estimate the number of people likely to be disturbed by a particular noise environment.

Comparison with previous studies

For two reasons, the principal comparison in this section will be with the Griffiths and Langdon study (4). Both the Traffic Noise Index and the Noise Pollution Level were derived from that particular data set, and the description of the work is sufficiently complete to allow a detailed comparison of approach, techniques, and findings. The results reported in the present paper differ considerably from those Griffiths and Langdon report, both in the degree of correlation between physical and social measures (they obtained at best $r = 0.60$ for the direct physical measures), and in the form of the equation which best matched the response data. Explanations for these differences can be found in both the questionnaire and the analysis techniques.

The question Griffiths and Langdon used dealt specifically with traffic noise, while our results are based on a question about overall neighbourhood noise. That these two questions yield different responses can be seen from another question in our study, which asked about reaction to specific noise sources, as well as reaction to the overall neighbourhood noise. For expressway traffic, the correlation (Kendall's tau for ordinal variables) between responses to the two questions was only 0.4026. We focused on the rating of overall noise for two reasons. First, it is rarely the case that only a single noise affects people, although people can certainly identify different noise sources, and talk about them separately. Second, any physical measure we could provide would be of ambient noise, not of noise from a single source. It seemed most legitimate to match overall noise records against reaction to overall noise.

The questionnaire used in the present study was introduced to respondents as a general neighbourhood survey, and the first two questions asked were, "What are the important things you like (don't like) about living in this neighbourhood?" Thus noise could be, and was, voluntarily mentioned before the study had been identified as focusing on noise. In a case such as this it is good practice to obtain some indication of the respondent's concern about noise before telling him or her that it is the interviewer's concern. It is not clear whether the survey Griffiths and Langdon report was able to do this.

The final point of difference is the interpretation of the response scale. There is some confusion in the analytical treatment of the Griffiths and Langdon scale. For example, they interpret the mid-point as "don't know", and then exclude such responses from subsequent analysis (4:21). They appear subsequently to calculate the arithmetic mean of responses for each site, in which case surely the scale mid-point should be included. The average score for each site is then used in a regression analysis, which requires an interval scale, and also argues for inclusion of the mid-point. Because of these analytical problems, the formula for TNI is necessarily questionable. In that L_{NP}, the noise pollution level, is based on the same set of data treated in the same way (5:282), so likewise is it questionable.

Conclusions

The study reported in this paper indicates that it is possible to predict, with a fair degree of reliability, the percentage of a group of people likely to be annoyed by noise from surface transportation solely on the basis of the daytime L_{75}, L_{50}, or μ. Because this is a surprising finding, several possible explanations for the difference between these and previously reported results have been explored, all of which appear to argue for the improved reliability of the results reported in this study.

Grounds for hesitation in accepting these results stem from two sources. First, the fact that only a single parameter of the noise profile is included means that the findings will be of use only in those areas where the set of noise profile parameters varies in the same way they have here. For example, if driving trucks at night were suddenly restricted, the noise profile of most highways would change drastically, and it is doubtful whether these results would still hold. Second, the selection of households at some of the sites included in this analysis deviates too far from the ideal. As additional data become available, they will be used to replace the faulty sites, to improve the analysis.

Nevertheless, the equations reported here represent reasonable ways to identify or predict the social impact of the noise from a road or rail line. This appears to represent a significant advance in our treatment of ground transportation noise.

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TABLE 1

Description of sample sites by noise source

Site	Housing Placement	Shielding	Day Monitored	Daytime L_{50} (dBA)	% Disturbed
Expressway					
1	ideal	light industry	Friday	48	17
2	ideal	none	Tuesday	68	56
3	ideal	housing row	Wednesday	59	57
4	fair	wooded area	Tuesday	62	43
5	bad	housing	Thursday	63	38
Arterial					
1	ideal	none	Wednesday	68	61
2	good	none	Friday	53	14
3	good	housing row	Thursday	48	36
Rail					
1	good	none	Monday	51	26
2	ideal	none	Thursday	45	19
Rail & Expressway					
1	ideal	none	Tuesday	53	17
2	ideal	commercial row	Tuesday	50	9
Control (quiet) areas					
1	-	-	Thursday	49	26
2	-	-	Tuesday	47	9

TABLE 2

Correlations of physical data with percentage of respondents expressing disturbance at noise

Noise measure	Daytime (0700-1900)	Evening (1900-2300)	Night (2300-0700)
		Time of Day	
L_{90}	.799[c]	.661[b]	NS
L_{75}	.838[c]	.681[b]	NS
L_{50}	.827[c]	.717[b]	.548
L_{25}	.797[c]	.711[b]	.675[b]
L_{10}	.758[c]	.622[b]	.658[b]
μ	.819[c]	.712[b]	.580
L_{eq}	.743[c]	.553	.548
σ	NS[a]	NS	.610[b]
$L_{10}-L_{90}$	NS	NS	.645[b]
L_{NP}	.660[b]	.493	.586
$\mu + 0.5\sigma$	.810[c]	.702[b]	.617[b]
TNI	.530	NS	.658[b]

NOTES:

[a]NS = coefficient not significant at the .05 level.
[b]coefficient significant at the .01 level.
[c]coefficient significant at the .001 level.

TABLE 3

Candidate regression equations for predicting percentage of population disturbed by noise

	Equation	R	Standard Error
(1)	$Y = -86 + 2.4\ L_{90}$ (day)	.799	11.3
(2)	$Y = -80 + 2.2\ L_{75}$ (day)	.838	10.3
(3)	$Y = -73 + 1.9\ L_{50}$ (day)	.827	10.6
(4)	$Y = -67 + 1.7\ L_{25}$ (day)	.797	11.4
(5)	$Y = -74 + 1.7\ L_{10}$ (day)	.758	12.3
(6)	$Y = -83 + 2.1\ \mu$ (day)	.819	10.8
(7)	$Y = 44 + 11.9\ L_{25}$ (day) $- 9.7\ L_{10}$ (day) $- 2.1\ \mu$ (night)	.904	8.8
(8)	$Y = -44 + 9.8\ \mu$ (day) $- 5.7\ L_{10}$ (day) $- 2.2\ \mu$ (night)	.922	8.0
(9)	$Y = -89 + 1.7\ L_{90} + 0.6\ L_{10}$	.808	11.6