Examination of Some Implicit Assumptions of Noise-Impact Analysis Techniques

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Implicit in the existing techniques for assessing the impact of transportation noise are several assumptions that warrant explicit examination. The authors of this paper use data collected in southern Ontario to examine three assumptions, expressed as testable hypotheses, that deal with the relationship between the subjective rating of specific noise sources and the rating of the overall level of neighborhood noise, the strength of this relationship as a function of the number of disturbing noises present, and the relationship between specific noise-source ratings and the total number of disturbing noises. In testing each assumption, a major hypothesis and alternative hypotheses are proposed and supporting explanations are suggested. The principal basis of hypothesis testing is to use nonparametric correlation analysis. The results show a significant positive relationship between the rating of specific sources and the overall noise rating, a tendency in the case of certain transportation-noise sources for this relationship to become stronger as the number of disturbing noises present increases, and a significant positive relationship between the rating of specific noises and the total number of disturbing noises. The major conclusion is that the results tend to support the implicit assumptions of existing procedures for assessing the impact of transportation noise. At the same time, they indicate the need to develop techniques that more closely relate to specific noise sources and that take into account the number of disturbing noises present.

Almost all of the commonly used procedures for identifying the impact of transportation noise on the community rely on several simplified assumptions about the relationships among particular noise sources (such as an expressway), overall noise levels in a residential area, and the way people respond to both the specific and the general noise levels. The importance of these assumptions can be clarified by considering two main ways to identify the impact of transportation noises.

The simplest approach involves predicting the noise levels generated by the transportation facility and matching them against some preselected standards. The identification of these standards is usually based on previous studies that obtained data on both noise measurements and community response. In fact, there is a considerable literature on this issue; it has resulted in the identification of a variety of measures of noise that correlate well with community response, e.g., L_{eq} (1), traffic noise index (2), or noise-pollution level (3).

The second approach carries the analysis one step further, by attempting to translate the impact on the community from a measurement in terms of noise to a measurement in terms of numbers of people affected. As has been pointed out (4), this approach has several advantages over the first but demands an even clearer understanding of the relationship between noise levels and the percentage of a population affected, which presumably must also have been obtained from previous studies.

The drawbacks of these two approaches are similar. First, in the previous studies on which both approaches rely, analysts could measure only the aggregate noise in a neighborhood. They could not generally measure the noise in a community produced by a single source, nor would it be reasonable to do so, given the manner in which decibel levels combined. This means that even when the analyst has interview data on community response to noise from a particular transportation facility, it must be matched against physical measurements of noise from all sources combined. On the other hand, the interview data can be matched to the physical measurements by using ratings of the overall neighborhood noise level, but in that case one must assume that the neighborhood noise rating is highly correlated with reaction to the transportation noise. Hence, whichever procedure is followed, it is necessary to assume a strong and direct relationship between the ratings for a specific source and those for the overall neighborhood. The first assumption to be investigated in this paper is:

1. The way an individual responds to general community noise levels is directly related to the way that person reacts to the specific noise sources that make up the general noise level.

If assumption 1 is true (and we certainly hope that it is), there remains the question of whether the number of disturbing noises present has any effect on either the strength of the relationship or the ratings of individual noise sources. Measurement procedures implicitly assume that it does not, since a term dealing with the num-

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ber of distinct types of noise sources is not included. On the other hand, practice in some instances seems to assume that the greater the number of types of noise present, the less important any one particular noise will be. For example, when truck routes through cities must be selected, routes that are already noisy are chosen rather than quiet ones. The two further assumptions to be discussed are:

2. The strength of the relationship between the rating of general neighborhood noise and the rating of a specific noise source is independent of the total number of noises rated as disturbing.

3. The rating of an individual noise is independent of the total number of noises rated as disturbing.

During a study undertaken to relate community responses to a range of noise sources, we collected data to examine the validity of these three assumptions. The reader should be aware that the analysis presented here is based on comparisons of different people in different noise situations. Field research precludes exposing particular individuals to a variety of noise environments, so it is misleading to interpret these results as indicative of the way in which a particular individual's reaction will vary. The results are, however, reliable across groups of people. Each of the three assumptions we examined is treated as a hypothesis; alternative hypotheses are also examined to provide a basis for strong inference (5).

DATA COLLECTION

The data base for the analysis reported in this paper was drawn from a study of community response to ground transportation noise in the Hamilton-Toronto area of southern Ontario. Two types of data were collected: physical measures of noise at each site for a 24-hour weekday and information on household attitudes and behaviors with respect to the noise. The analysis reported in this paper is based only on the household data, which were obtained through a carefully constructed and pretested questionnaire administered to 837 respondents—approximately 30 from each of 28 sites. A comprehensive set of questions was asked to determine various aspects of residents' attitudes and behavioral responses to noise, including responses to specific noise sources rather than simply a general neighborhood rating of noise, as has been common in previous community studies (6, 7).

A distinguishing feature of the questionnaire design was the use of a bipolar rating scale for measuring the intensity of respondents' reactions to specific and general noise levels. Previously, the practice has often been to employ unipolar disturbance or annoyance scales. This procedure was not followed in the present study because it prevents the respondent from indicating a positive response to noise. In the pretest, when a unipolar disturbance scale was used, the interviewers noted that in many instances a positive response occurred, particularly in rating the general level of neighborhood noise; we therefore adopted a bipolar scale in the major data-collection phase. A nine-point scale ranging from extremely agreeable to extremely disagreeable, with a neutral midpoint, was employed. Thus the study did not proceed on a definition of noise as unwanted sound, as most previous studies have done.

The 28 sites used in this study were selected to provide a number of locations within each of seven noise-environment categories. The primary criterion for site selection was the dominant nonresidential noise source, with particular emphasis on transportation facilities. An attempt was made to include sites in which a single source acted in isolation and others in which two or more sources were combined. An additional concern was to vary the degree and type of shielding at each site. Finally, a sufficient amount of housing paralleling the noise source had to be present to allow 30 interviews to be completed within the same noise environment. The sites are categorized as follows: 8 expressway sites, with 237 respondents; 6 arterial roadway sites, 165 respondents; 4 main rail-line sites, 122 respondents; 3 secondary rail-line sites, 90 respondents; 2 sites exposed to both expressway and rail noise, with 58 respondents; 2 sites at industrial or commercial interfaces with transportation facilities, 60 respondents; and 3 quiet residential sites, 105 respondents.

A deliberate effort was made to vary the socioeconomic characteristics of the respondents among the sites, and to obtain a representative set of respondents within each site. Tabulation of the personal data showed that the sample contained a cross section of the general population with respect to the age, educational level, and income of the respondents. There was a bias toward female respondents, who made up 75 percent of the sample, and an associated bias toward housewives. Several statistical tests on the data have indicated no significant differences between housewives and other occupational groups in the response to noise, however, so this overrepresentation should not bias the results.

Sampling across this range of sites ensured the desired variance in the exposure of respondents within the sample to transportation noises while, at the same time, yielding a sufficient number of responses from each type of site to make aggregate comparisons reliable.

EXAMINATION OF ASSUMPTION 1

The first and most important of the assumptions implicit in most techniques for measuring the community impact of noise, stated as a hypothesis together with two other possible hypotheses, is that

1.A. The way an individual assesses the general neighborhood noise level is positively related to the way that person reacts to the specific noise sources that make up the general noise level.

1.B. The neighborhood noise rating is inversely related to that for specific sources.

1.C. There is no relationship between the neighborhood noise rating and the rating of specific sources.

Certainly the original hypothesis is the most plausible of the three. Hypothesis 1.B may perhaps hold for one or two particular sources, in which case one might be tempted to comment more on the importance of that source than on the hypothesis. The presumption in favor of hypothesis 1.A is so strong, in fact, that evidence in favor of 1.C might be dismissed on the basis of insufficient data. The first assumption is so intuitively appealing that it is hard to derive plausible explanations or interpretations of alternative hypotheses a priori.

The most obvious approach to use in testing these hypotheses is to investigate the correlation between the neighborhood noise rating obtained from each respondent and the rating of each noise mentioned. These data constitute valid ordinal scales but certainly have no validity as interval- or ratio-scaled data. Hence either Spearman's or Kindall's correlation coefficient is an appropriate statistic. Given the large number of data points and the relatively small number of scale points, there will be a large number of tied ranks. Hence Kendall's tau was selected as the correlation coefficient throughout the analysis (8); the results are as follows.

Noise Source	Number of Cases	Coefficient	Significance
Expressway traffic	206	0.4062	0.001
Arterial traffic	86	0.2573	0.001
Local traffic	130	0.2638	0.001
Trucks	189	0.3948	0.001
Trains	209	0.1517	0.001
Aircraft	73	0.3359	0.001
Motorcycles	194	0.0986	0.05
Children	161	0.2409	0.001
Pets	114	0.2478	0.001
Garden machinery	54	0.1587	0.05

It should be noted when interpreting these figures that the number of cases varies for each of the noise sources; the correlations are therefore based on different subsets of the total sample. This is inevitable, given that in general people in different locations are exposed to different noise sources. These figures indicate the relationship between an individual's overall rating of neighborhood noise and the rating of an individual noise source for those respondents who mentioned that they noticed the particular noise. The 10 specific noise sources listed are a subset of the 20 sources included in the questionnaire. Attention is restricted to these in the analysis since they were the only ones mentioned by more than 5 percent of the sample.

In general, the results shown above tend to support hypothesis 1.A, namely, that there is a positive relationship between the rating of individual noise sources and the rating of the general neighborhood noise. Further, they suggest that this relationship is strongest for transportation-noise sources. With the exceptions of trains and motorcycles, all transportation-noise sources correlate more strongly with the neighborhood rating than do any of the other sources.

Hypothesis 1.B is clearly rejected since none of the coefficients are negative. With the exception of perhaps three sources, hypothesis 1.C would also appear to be rejected, since seven of the coefficients are greater than 0.24 and are statistically significant at the 0.001 level. Marginal support for hypothesis 1.C comes from motorcycles, garden machinery, and trains. All three have low coefficients and the first two are the least significant of all those in the table (significant at 0.021 and 0.046 respectively). Plausible explanations can be developed for these three. Motorcycle noise, while disturbing, is in most instances a relatively infrequent occurrence and is therefore not likely on its own to be a major influence on the overall noise rating. Noise from garden machinery may again be disturbing but is normally accepted in the neighborhood because at some time most people are responsible for creating it; in addition it signifies that properties are being maintained. The low correlation in the case of trains reflects the general ambivalence about this source. On many occasions, particularly at secondary rail sites, people expressed a favorable response to train noise even though they may have rated the overall noise level as disagreeable. In other instances, the specific and general ratings were consistent. The net result is a low correlation.

The remainder of the paper will focus on the sources listed above, omitting garden machinery because of its low correlation and significance but retaining the motorcycle (despite these same factors) since it is a transportation mode.

EXAMINATION OF ASSUMPTION 2

The preceding section has supported the assumption that there is a positive relationship between the rating of an individual noise and that of overall neighborhood noise. The implicit assumption in most noise-impact analysis is that the relationship is independent of the number of different noise sources that disturb someone. That assumption can be stated here as a hypothesis, along with its most obvious alternatives.

2.A. The strength of the relationship between the rating of general neighborhood noise and that of a specific noise is independent of the total number of noises that disturb the individual.

2.B. The strength of the relationship between the two ratings increases as more disturbing noises are reported.

2.C. The strength of the relationship decreases as more disturbing noises are reported.

The first hypothesis, which is the assumption being tested, is intuitively appealing because it implies, first, that people are consistent in their assessment of a particular noise and, second, that the analyst does not need to worry about the number and types of other noises present in assessing the impact of any single noise source (for example, a new highway or transit line).

Alternative 2.B, if verified, can be explained only on the basis of the way in which people evaluate community noise. In particular, it would have to be based in some way on mutually reinforcing effects. For example, if an expressway is the only noise source disturbing people, they may weight this in a variety of ways to arrive at an overall neighborhood noise rating, so that the strength of the resulting relationship is quite low. If, however, an expressway, trucks, and children are all disturbing, the weightings for each may be more consistent among a group of people, which would result in an apparently stronger relationship. A related interpretation of alternative 2.B is that the relationship is strengthened as the number of disturbing noises increases because people who are more disturbed are more likely to hold definite opinions about specific noises and hence to give more precise ratings. In this sense, the strengthening of the relationship is a function of the decline in error variance of the ratings as the number of disturbing noises increases.

For alternative 2.C, two explanations are plausible. The first is based on the physical nature of noise, as expressed in the dBA scale, for example. The nature of the additivity of sounds means that the overall level is mostly a function of the noisiest single source. Therefore, if there is only one disturbing source, it should be more strongly related to the physical measure of total neighborhood noise, and hence to the rating of it, than if there are several disturbing sources. Alternatively, 2.C can be explained on the basis that, as the number of disturbing noises increases, there are simply more sources to contribute to the overall rating; hence the importance of each declines.

As for assumption 1, the appropriate statistics to use here are the Kendall's τ correlation coefficients, stratified this time by the number of disturbing noises; see Table 1. A more detailed breakdown for more than two disturbing noises was precluded by the need to maintain reasonable sample sizes. It was possible to calculate the coefficients even in cases in which no disturbing noises were mentioned because the bipolar scale allowed respondents to rate specific noise sources as agreeable or neutral. The substantial sample sizes associated with no disturbing noises appear to confirm the importance of using a bipolar rating scale.

A striking feature of the table is the number of nonsignificant correlations, which is partly a function of the reduction in sample sizes that resulted from the stratification of the data set. In addition, the correlations in the first column are probably low because there were fewer variations in the rating of the specific source; since it was not disturbing, only half of the scale is used.

Table 1. Correlations of specific noise source ratings with the neighborhood noise rating, by number of disturbing noises.

	No Disturbing Noises			One Disturbing Noise			Two Disturbing Noises			More Than Two Disturbing Noises		
Noise Source	Number	Coefficient	Significance	Number	Coefficient	Significance	Number	Coefficient	Significance	Number	Coefficient	Significance
Expressway traffic	57	0.0056	NS	69	0.2349	p = 0.01	50	0.3610	p = 0.001	30	0.4400	p = 0.001
Arterial traffic	28	0.1863	NS	30	-0.1188	NS	24	0.4311	p = 0.01	4	—	—
Local traffic	46	0.2757	p = 0.01	42	-0.1079	NS	22	-0.0641	NS	15	0.2909	NS
Trucks	39	-0.0107	NS	54	0.2338	p = 0.01	62	0.3772	p = 0.001	34	0.2233	p = 0.01
Trains	80	0.1735	p = 0.05	70	0.0053	NS	36	-0.1937	p = 0.05	23	0.0303	NS
Aircraft	27	0.0607	NS	18	0.0604	NS	15	0.3670	p = 0.05	13	0.3466	p = 0.05
Motorcycles	29	-0.0704	NS	62	-0.2312	p = 0.01	60	0.0428	NS	43	-0.0138	NS
Children	77	0.1684	p = 0.05	36	-0.0555	NS	27	0.2245	NS	21	-0.0448	NS
Pets	31	0.3290	p = 0.01	31	-0.0665	NS	26	-0.0626	NS	26	0.0352	NS

Table 2. Correlation of specific noise source ratings with number of disturbing noises.

	All Respondents			Respondents Who Reported Some Disturbing Noise		
Noise Source	Number	Coefficient	Significance	Number	Coefficient	Significance
Expressway traffic	210	0.596 15	p = 0.0001	152	0.379 27	p = 0.0001
Arterial traffic	89	0.545 39	p = 0.0001	60	0.215 56	p = 0.01
Local traffic	130	0.526 18	p = 0.0001	84	0.392 29	p = 0.0001
Trucks	191	0.577 29	p = 0.0001	152	0.317 64	p = 0.0001
Trains	213	0.385 34	p = 0.0001	130	0.120 24	p = 0.05
Aircraft	74	0.459 73	p = 0.0001	46	0.238 19	p = 0.01
Motorcycles	196	0.455 08	p = 0.0001	167	0.282 26	p = 0.0001
Children	162	0.398 47	p = 0.0001	85	0.405 26	p = 0.0001
Pets	116	0.469 86	p = 0.0001	84	0.332 96	p = 0.0001

Examining the coefficients by row suggests that for many of the noise sources no consistent trend occurs, which appears to support hypothesis 2.A—that the strength of the relationship between the ratings of general neighborhood noise and of specific noise sources is independent of the total number of disturbing noises mentioned. There are, however, some important exceptions to this general result, expressway traffic being the prime example. In this case, the coefficients consistently increase from a nonsignificant value (0.0056) when no disturbing noises are reported to a highly significant value (0.4400) when more than two are reported. This result seems to refute 2.A and support 2.B. A similar but less consistently maintained trend applies with respect to arterial traffic, truck, and aircraft noise.

No single conclusion can be drawn from these results. The coefficients for five of the nine noise sources seem to support 2.A, since in these cases the relationship with the overall neighborhood rating does not vary consistently with the number of disturbing noises mentioned. For the remaining four sources, the coefficients appear to support 2.B, most clearly in the case of expressway traffic. The results provide no support for hypothesis 2.C. As suggested earlier, the most plausible explanation for hypothesis 2.B is that respondents tend to be more internally consistent in their ratings of both specific and general noise levels when they are disturbed by a number of different sources. In addition, it is important to notice that support for hypothesis 2.B emerged for the four noise sources that had the strongest relationship overall with the neighborhood rating shown above.

EXAMINATION OF ASSUMPTION 3

The third assumption implicit in present noise-impact analysis techniques is that the rating of a specific noise source is independent of the total number of noises that disturb the individual. If the assumption holds, then the way people react to expressway noise, for example, should not be affected by whether they also report being disturbed by trucks and children. The assumption and its alternatives can be stated as the following hypotheses.

3.A. The way a specific noise source is evaluated by an individual is independent of the total number of noises mentioned as disturbing.

3.B. The individual is more disturbed by a particular noise as the number of disturbing noises increases.

3.C. The individual is less disturbed by a particular noise as the number of disturbing noises increases.

From the point of view of validating current approaches to noise-impact analysis, the confirmation of 3.A is appealing. Plausible explanations can be suggested, however, for 3.B; for example, some noises may combine several sources so that there is a physical causal connection between an increase in a specific noise and the number of contributing sources. A case in point is that expressway noise may be more disturbing when trucks are also disturbing, if trucks are a component of the expressway noise. A second explanation is based on the existence of a carry-over effect such that, once disturbed by a particular noise, an individual is more likely to be disturbed by other sources. A hypothetical example is that of a person who ordinarily is undisturbed by children but finds their noise disturbing once his irritation level has been raised by the noise from trucks.

The basic procedure used to test the hypotheses developed from assumption 3 was again to calculate Kendall τ coefficients as measures of the relationship between each noise source and the number of disturbing noises mentioned. Two sets of coefficients were calculated, one that included and one that excluded respondents for whom no noises were disturbing. The rationale for this was that, by the definition used in the study, if no noises were disturbing, then the source(s) mentioned must have been rated as agreeable or neutral. Hence, it could be argued that the inclusion of respondents for whom no noises were disturbing would lead to an artificial inflation of the correlation coefficients.

Table 2 shows the two sets of coefficients. (The number of respondents for each noise in this table may be greater than the total numbers in the two previous tabulations because a few people did not give an overall neighborhood rating.) As expected, the magnitude of the coefficients is less when the respondents who mentioned no disturbing noises are excluded, except for the case of noise from children, where the coefficient was slightly higher. Despite these differences all the values are positive and significant, which is contrary to hypothesis 3.A and hence leads to the conclusion that the rating of specific noises is not independent of the total number of disturbing sources. Since the coefficients are all positive, there is support for alternative hypothesis 3.B, which implies that, as the number of disturbing noises increases, specific sources are likely to be rated as more disagreeable. The statistical significance of the correlations and the fact that they are consistent for a range of noise sources provide a strong basis for this conclusion.

Of the two explanations suggested for this relationship, the notion of a carry-over effect that leads disturbance from one source to trigger unfavorable responses to other noises seems the more likely. A recent case in Toronto seems to support this possibility. Residents close to an entertainment area complained about the noise from cars as drivers repeatedly circled the area looking for parking space. There was an additional complaint against the noise theater patrons made walking to and from their cars. It seemed on the evidence presented that the second complaint was very much a carry-over from the first and would not have arisen nearly as often had the traffic noise not first raised the annoyance levels in the neighborhood.

SUMMARY AND CONCLUSIONS

The aim of this paper has been to examine three assumptions implicit in existing approaches to noise-impact analysis. The results presented lead first to the conclusion that there is a significant positive correlation between an individual's rating of specific noise sources and his rating of the overall level of neighborhood noise.

This finding supports the implicit assumption of existing community noise-measurement procedures and to that extent is reassuring. On the other hand, the magnitude of the correlations for several of the sources was relatively low, and none exceeded 0.50. Caution should therefore be exercised when treating community response to specific noises by using physical measures based either on all sources combined or on ratings of the overall neighborhood noise level. It is fortunate that the results show the strongest relationships in the case of transportation noise since this has been the major focus of noise-impact analysis. Train noise does, however, stand out as having a relatively low correlation with the overall neighborhood rating, which indicates in this case that measures related to overall neighborhood noise levels are probably unreliable as bases for estimating the impact of the specific source.

Examination of the second implicit assumption failed to produce a clear-cut conclusion. For five of the nine sources, the relationship between the rating of the specific noise and the overall neighborhood rating appeared to be independent of the number of disturbing noises mentioned, which supports the assumption. However, for four sources the results tended to refute the assumption, since they showed a strengthening of the relationship as the number of disturbing noises increased. This creates some cause for concern, since existing techniques of noise-impact analysis typically do not take account of the number of disturbing noises present. The implication of the findings is that this may be a significant factor, particularly with respect to response to transportation noise.

Further evidence for this conclusion is found in the results of testing the third assumption. Contrary to the basic hypothesis, it emerged that the rating of a specific noise is not independent of the total number of disturbing noises but rather is significantly and positively related. This result was true for all sources tested and was most decisive in the case of road traffic noise.

These conclusions leave us in some doubt as to the adequacy of the techniques used to assess the impact of transportation noise that are based on overall measures of neighborhood noise and that make no allowance for the number of disturbing noises present. As indicated in the introduction, both factors are characteristic of a number of existing procedures. The general implication of the results of the analysis presented here is that such procedures, while not invalid, are at best crude tools for assessing community response to specific noise sources. There would certainly appear to be a need to develop more refined techniques that are less subject to the limiting assumptions examined in this paper.

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