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DESIGNING COMMUNITY SURVEYS TO PROVIDE A BASIS FOR NOISE POLICY

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16 Abstract

After examining reports from a large number of social surveys, two areas have been identified where methodological improvements in the surveys would be especially useful for public policy. The two study areas are: the definition of noise indices and the assessment of noise impact. Improvements in the designs of surveys are recommended which would increase the validity and reliability of the noise indices. Changes in interview questions and sample designs are proposed which would enable surveys to provide measures of noise impact which are directly relevant for public policy.

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DESIGNING COMMUNITY SURVEYS TO PROVIDE A BASIS FOR NOISE POLICY

James M. Fields

SUMMARY

After examining reports from a large number of social surveys, two areas have been identified where methodological improvements in the surveys would be especially useful for public policy. The two study areas are the definition of noise indices and the assessment of noise impact.

A noise index consists of a measured noise level, a set of environmental factors (both acoustical and nonacoustical) and a corresponding set of corrections to the measured noise levels which are associated with each environmental factor. The values of these index factor corrections are most appropriately defined through multiple regression analyses of social survey data. Multiple regression analyses also provide a convenient framework for considering the assumptions which are implicit in noise index models. The validity and reliability of the surveys' estimates of the noise indices' correction terms will be increased if (1) surveys are designed to meet specific accuracy goals, (2) objective measurements are made of both acoustical and nonacoustical environmental factors, (3) the precision of the studies' measurements of the noise index factors (including noise level) is known, (4) observations are spread over a wide range of values for each index factor, (5) the index factors are not highly correlated in sample designs, (6) precise measures of annoyance are used, (7) large numbers of interviews and study areas are included, (8) probability sample designs are adopted, and (9) some noise impact questions are shared between surveys.

Community surveys can better assess noise impact if (1) questionnaires include questions which can be directly quoted to evaluate noise impact and (2) probability samples are drawn from well-defined populations.

INTRODUCTION

Social surveys of people's responses to noise in residential areas have made many contributions to public policy. However, the surveys' designs and analysis techniques have often severely limited their usefulness in the two areas of noise impact assessment and noise index definition. This paper draws together noise survey innovations as well as accepted survey design principles to suggest survey design characteristics which would provide better information for public policy.

NOISE INDICES

Most environmental noise regulations incorporate noise indices which attempt to take into account the effects of noise on people. Noise indices often contain both acoustical and nonacoustical components. The selection of such noise indices is, therefore, an important noise policy issue, especially at national and international levels. Virtually all indices have three components: (1) a noise level measure which is a purely acoustical descriptor of the noise during some time period,(e.g., 24 hour L_{eq}, average peak noise level, L_{10}), (2) other index factors (both acoustical and nonacoustical) which are allowed to influence the value of the index, and (3) weights or corrections to the index which are associated with each index factor. Factors used in existing indices include: time of day, ambient noise level, community zone (ref. 1), number of noise events, duration, noise source, tonal content, impulsiveness, daily variation in noise level, repetitiveness of sound, season of year, climate, exposure history, and noise source's relation with community.

There is considerable disagreement about the weightings to be assigned to the above factors and even which of the factors should be included in the indices. There is general agreement that the basis for assigning factor weights should be the factors' effects on people's reactions to noise. It is also widely assumed that the indices should ideally be validated with data gathered in community settings. Realistically, it is recognized that a few factors can probably never be successfully studied in community settings. This is true when the factors of interest are so highly correlated that their effects are confounded. For example, the sound levels of 1/3-octave bands from aircraft are so highly correlated and confounded in community settings that the effects of different frequency network weightings or tone corrections can not be evaluated in community surveys. Surveys are more useful in studying other noise index factors, especially time of day, ambient noise level, number of noise events, and type of noise source. In spite of the acceptance of the value of social surveys, only a few have been specifically designed to provide estimates of the correction weights for the noise index factors.

Part of the reason for the lack of recent social survey attempts to define new noise indices can be traced to experiences with past community noise surveys. Early social surveys did use their data to define new indices. Later surveys, however, could not replicate the earlier findings. Thus, the survey methodology appeared to provide results which were too unreliable to be useful. This paper suggests that enough has been learned about community noise survey methodology so that reliable estimates of noise index parameters can now be derived from properly designed noise surveys.

Analysis Methods for Deriving Noise Indices

Multiple regression approach.- Multiple regression analysis is especially well suited for deriving noise indices because both multiple regression and the noise indices are based on similar additive linear models. The regression of an individual's annoyance on a set of acoustical and nonacoustical variables, i.e., noise index factors, can be mathematically expressed in a multiple regression equation of the form:

$$A_i = a + B_L L_i + B_1 F_{1i} + B_2 F_{2i} + \ldots . + B_n F_{ni} \quad (1)$$

where

A_i = a response score (such as annoyance) for person "i"

a = the constant, intercept term

L_i = noise level for person "i"

B_L = the partial regression coefficient for noise level controlled for all of the "n" other variables included in the equation

$B_1, B_2 \ldots . B_n$ = the partial regression coefficients for each of the other index variables

$F_{1i}, F_{2i} \ldots F_{ni}$ = the values for each of the index variables (such as ambient noise level, noise source, number of events) for person "i." (The time-of-day correction uses a slightly different model which will be discussed later.)

If the right side of this equation is then divided by the noise level partial regression coefficient (B_L), the ratios of the partial regression coefficients (B_1/B_L, $B_2/B_L \ldots$) are the empirically derived weights or corrections expressed in decibels per unit change of $F_1, F_2 \ldots . F_n$ which could be directly applied to each of the factors in the noise index. The noise index can then be expressed as:

$$\text{Noise Index} = L_i + B_1/B_L\ F_{1i} + B_2/B_L\ F_{2i} + \ldots . + F_n/B_L\ F_{ni} + a/B_L \quad (2)$$

The constant term (a/B_L) can then be replaced by any constant which gives convenient index values. The noise index is formed for any one person "i" by starting with the noise level (L_i) and adding on decibel corrections for each of the other index factors.

The regression approach can be illustrated and contrasted with a correlational approach with data from the 1967 Heathrow survey (second Heathrow survey, ref. 2). First annoyance is regressed on noise level, number of noise events and ambient noise level. This gives the following regression equation:

$$A = -213 + 2.32L + 12.20(\text{Log}_{10}N) - 1.70B \quad (3)$$

where

A = aircraft noise annoyance ("very" annoyed = 100, not "very" annoyed = 0)

L = average peak noise level (PNdB) of aircraft noise events over 80 PNdB

N = average number of noise events per 24 hours (averaged over 3 months)

B = ambient (background) noise level (1 = within 2 minutes walk of a main road, 0 = if further away)

(Only respondents above 90 PNdB with less than 300 noise events a day are included in the analysis because relationships were not clearly linear beyond these limits. Not enough data are available to assess relationships when there are less than 10 noise events a day.)

This shows that a one decibel increase in noise level increases the number of "very" annoyed people by 2.32 percent, a tenfold increase in number of noise events increases annoyance by 12.20 percent, and that being in a residence near a main road decreases aircraft noise annoyance by 1.70 percent.

When the equation is divided by the partial regression coefficient for noise level (2.32), the the following equation gives noise index corrections for each factor:

$$\text{Noise Index} = L + 5(\text{Log}_{10}N) - 1A + \text{Constant} \qquad (4)$$

This offers two quite useful pieces of information to a policymaker in a noise index form: (1) A tenfold increase in number of events is equivalent to a 5 dB increase in noise level and (2) the change from the low to high ambient noise level condition is equivalent to a one decibel decrease in average peak noise level. (The very crude indicator of ambient noise level available in this survey obviously limits the value of the statement.)

A correlation analysis of the same data shows that 7 percent of the variance in annoyance is explained by the three variables: 5 percent being attributable to noise level, 2 percent to number of events, and less than 0.5 percent to ambient noise level. These particular values of the partial correlation coefficients are not stable descriptions of the relationship but are very heavily dependent upon the sample design. Even if they were stable, these correlational statistics do not provide information which is directly useful to the policymaker.

One complexity should be noted. The simple regression model in equations (1) and (2), assumes that the effects of noise measured in decibels, not sound energy, are additive. For conventional time-of-day weighting indices (L_{dn}, NEF, CNEL), it is the energy levels which are directly weighted, not the decibel levels. For two time periods, annoyance is assumed to be proportional to:

$$10\ \text{Log}_{10}\left[B_D(\text{antilog}\ L_D/10) + B_N(\text{antilog}\ L_N/10)\right] \qquad (5)$$

where

L_D = daytime noise level (decibels)

L_N = nighttime noise level (decibels)

B_D, B_N = the respective partial regression coefficients for day and night

Once again, a regression approach can be taken. After the equation has been transformed by taking its antilog, it is possible to estimate a noise index with values which are a function of the daytime noise (antilog $L_D/10$) plus a ratio of nighttime to daytime partial regression coefficients (B_N/B_D) multiplied by the nighttime noise (antilog $L_N/10$).

Assumptions of the noise index and multiple regression models.- Neither the additive noise model implied by the noise indices nor the regression analysis technique (which makes explicit the noise index assumptions) can be accepted uncritically. In fact, a major goal of a noise index analysis should be to test the implied models. The decibel vs. energy weighting issue discussed above is just one of several aspects of the noise index models which must be examined.

For multiple regression to be a useful descriptor of a relationship, it must be reasonable to assume that the underlying relationship is linear and that the effects of the various independent variables on the dependent variable are additive. When inferential statistical techniques are used for small samples, the additional assumption of multivariate normality must be made (the distribution of dependent variable scores are normal with equal variances for all independent variables' values). The multivariate normality assumption is relatively unimportant for typical noise surveys because most of the data appear to have reasonably similar variances across noise levels (ref. 3) and because the small departures from normality are rendered insignificant by the large numbers of observations. The linearity and additivity assumptions are, however, critical and require further discussion.

The linearity assumption implies that each of the noise index factors must be linearly related to annoyance. Most noise survey data indicate that the most critical of these relationships (the annoyance by noise level relationship) is reasonably linear over restricted noise ranges and for moderate or high noise levels. However, if a study extends over a broad range of noise levels and includes low noise levels there are almost always nonlinear relationships. The degree of nonlinearity depends upon the type of human response being measured and the survey examined. Although nonlinear relationships could be included within a multiple regression framework (most easily by transforming the noise variable), this would violate the noise index model assumptions. The ratios of the partial regression coefficients could no longer be simply interpreted in terms of constant noise level corrections.

The additivity assumption implies that there is no interaction effect for the independent variables; that is, that each of the index factors must have the same net effect on noise annoyance regardless of the value of the other independent variables. For example, a warm climate/cold climate difference for annoyance must be assumed to increase aircraft noise annoyance just as much when the aircraft noise levels are 90 dB as when they are 60 dB. The additivity assumption has not been as widely examined in noise surveys. Although occasional interaction effects are reported, they have not been tested for significance (refs. 4,5,6).

There are standard statistical tests for both the linearity and additivity assumptions, but they can be easily calculated only if the researcher accepts simple random sampling assumptions which are inappropriate for most noise surveys. A more feasible first (and perhaps final) step for most analyses is to examine a plot of the grouped data such as is provided in figure 1. In these data from the British railway noise survey (ref. 7), there is a pronounced nonlinear trend in the noise annoyance relationship below 55 L_{eq} as well as an interaction of traction type with noise level. (Traction type affects annoyance above 45 L_{eq}, but not below.) Above 55 L_{eq} both the additivity and linearity assumptions appear to be reasonable. Since noise regulations usually concern levels above 55 L_{eq}, the relationships can still be stated in the conventional noise index correction terms for most noise policy purposes.

It is possible that annoyance is affected less by all index variables, as well as noise level,at low noise levels and thus that the noise level and other variables' partial regression coefficients with annoyance may all be reduced. If so, the ratios of the partial regression coefficients (the noise index corrections) might not change greatly over the noise levels in spite of the violation of the linearity and additivity assumptions.

The multiple regression technique also assumes that the dependent variable (annoyance) has the properties of an interval scale. In fact, the multiple point annoyance scale used in most surveys should be strictly defined as having only ordinal properties. The seriousness of the violation of this assumption is a subject of debate in the statistical literature. The assumption that reaction measures have interval scale properties has been made on the bases that (1) past noise survey analyses based on interval level assumptions which have been repeated with ordinal analysis techniques have found no bases for rejecting their original conclusions (refs. 8,9), (2) alternative reasonable assumptions about distances between scale points do not alter conclusions (ref. 9), and (3) statistics based on the weaker ordinal assumptions cannot be used to estimate numerical values for noise indices.

<u>Determining the precision of the study results</u>.- The estimate of the noise index factors' weights (corrections) are of little use to the policy-maker unless information is provided about the precision (e.g., 95 percent confidence interval) for the estimates. Since even very small reductions in noise level can be very expensive to the transportation industry, almost any

size correction could be potentially important for policy. The difficulty is in determining whether the correction estimated from the sample is likely to be reliable. If the policymaker overestimates the reliability of the findings, then unnecessarily complex regulations may be adopted. If the policymaker underestimates the reliability then some noise regulations will not be adopted which could have given as much relief to the population as much more expensive noise reduction measures.

The accuracy of the index factors' weights is based on estimates of the variance of the correction term ($\sigma^2_{B_F/B_L}$). It is necessary to first determine whether the weight for a factor "F" (B_F/B_L) is significantly different from zero and thus whether the factor should be included at all. If it is statistically significant, then confidence intervals can be placed around the ratio. It is also necessary to determine whether the weight calculated from a new study is significantly different from weights contained in existing indices. It is this test for the significance of the difference of the weights which guards against the unnecessary proliferation of indices.

The sample design must be taken into account if any of these statistics are to be calculated. For simple random samples, the variance of the ratio B_F/B_L can be calculated from a formula which will be discussed later in this paper (Eq. 9). For the complex samples which are more characteristic of most noise studies, the simple random sampling formula will mislead the researcher into thinking that his results are much more precise than they in fact are. What is needed are statistical methods for complex studies which take account of the complex sample design. Appropriate methods include balanced repeated replication, jackknife replication, and the Taylor expansion method (ref. 10). Some of the data from the British railway survey indicate that the true variance for regression statistics could be two to three time the variance estimated using simple random sampling assumptions (ref. 11).

All these inductive statistics assume that the data come from a probability sample. The case for a probability sample design will be discussed in a later section.

Designing Surveys for Noise Index Information

It has been seen that the critical output from a noise survey analysis which defines the noise index corrections is a calculation of the ratio of partial regression coefficients. All aspects of the survey must, therefore, be designed with the objective of creating valid, precise estimates of this ratio of the partial regression coefficients. Of course, there must also be careful adherence to the standard social survey and noise survey data collection techniques which insure high quality data. Such standard techniques have been discussed elsewhere and need not be reviewed here (refs. 12, 13, 14). Instead, three specific design problems will be discussed which are especially relevant for the calculation of noise index statistics.

Index factor measurements.- During a study's data collection phase, it is necessary to measure each of the factors which is to be tested for inclusion in a noise index. The required annoyance reaction which is to be used as a dependent variable in the regression analysis is an attitudinal characteristic of an individual. The noise index factors are, however, acoustical and nonacoustical characteristics of local environments and not attitudinal or demographic characteristics of individuals. The measurements of these environmental characteristics must not be based on the perceptions of the survey respondents. Evidence on this point comes from the British railway survey, where both environmental characteristics and respondents' perceptions of those characteristics were measured.

In the British railway survey, the quality of the non-noise environment was measured directly by having the trained observer-acousticians rate five aspects of the environment. (See the Appendix for the rating scheme.) Respondents were also asked for their perceptions of the quality of these environmental characteristics and for their overall satisfaction with the area.

The observer's rating is the measurement of neighborhood quality which is relevant for a noise index. When annoyance is regressed on noise level and the observer's rating, the regression equation is:

$$A = 1.4L_{eq} + 4.4F_0 - 60.0 \qquad (6)$$

where

A = annoyance (100 = high, 0 = low. High annoyance is defined as a score of at least 6.5 on a 5 item railway annoyance index; ref. 15)

L_{eq} = 24 hour L_{eq} dB(A)

F_0 = observer's rating of area (1 = high, 0 = low on index described in an appendix to this paper)

(Only respondents above $45L_{eq}$ are included in this analysis.)

On the average, 4.4 percent more people in high-quality neighborhoods were annoyed than in low-quality neighborhoods. If the ratio of the two partial regression coefficients is calculated, the correction for a high-quality non-noise environment is +3dB (4.4/1.4). This is statistically not significantly different from zero and, thus, it is concluded that a correction for non-noise environmental quality should not be included in an index.

Quite a different conclusion is reached if it is erroneously believed that respondents' perceptions can be substituted for an observer's rating of the non-noise environment. This regression equation is:

$$A = 1.4L_{eq} - 17.8F_R - 48.9 \qquad (7)$$

where

F_R = respondent's perception of area (1 = "very" satisfactory, 0 = "less than very" satisfactory)

In this case, the correction factor for "neighborhood quality" of -13 dB (-17.8/1.4) is statistically significant ($p < 0.05$). This simply shows that in this survey, as in other surveys (refs. 5,8), some respondents' positive feelings about the neighborhood environment are associated with a lack of annoyance with the noise environment. This relationship appears to be caused by a general, relatively undifferentiated evaluation of the whole neighborhood which influences some people's feelings about the noise environment. The real differences in the nonacoustical neighborhood environments were shown above to not affect people's feelings about the noise.

Based on the above analysis, it might be wondered whether the observer's ratings of the non-noise environment are valid measures of the aspects of the neighborhood which respondents value. A construct validation approach was taken by examining the relation between the observed non-noise environment and the respondent's perception. It was found that the areas which observers rated as high on environmental quality also tended to be rated more highly by respondents on general environmental quality. Thus, there is evidence for the validity of the observer's ratings.

From the above analysis, it can be seen that the objectively measured quality of the non-acoustical neighborhood environment is not related to noise annoyance. This was also found to be true for some other aspects of the non-acoustical environment which were measured in the British railway survey but have not been described here. Respondents' perceptions of the environment clearly cannot be substituted for observations by disinterested, trained observers when noise indices are being defined for public policy purposes.

Precision of index factor data.- The value of a social survey of noise annoyance, as of any research study, depends upon accurate data. For these surveys, random error in the index variable data can seriously bias the estimates of the regression coefficients. Random errors in the annoyance measures do not have the same biasing effect. ("Bias" is used in the technical statistical sense as a characteristic of an estimation procedure which gives an expected value over a number of trials which is not the true value in the population but is systematically too high or too low.) Random error in specifying the value of noise index variables for each interviewed individual results in attenuated (downwardly biased) estimates of the partial regression coefficients. Lack of precision in measuring both the acoustical and nonacoustical index variables could arise from insufficient sampling of varying environmental (including noise) conditions or from errors in measuring the selected samples of the environment. Noise sampling problems are so great, at least for aircraft noise, that they cannot be neglected (refs. 16, 17).

If the variability induced in the estimates of the index variables is normally distributed, the effects on the estimates of the regression coefficient can be expressed as (ref. 18):

$$B_T = B_o \left(1 + \frac{\sigma_e^2}{\sigma_o^2 - \sigma_e^2}\right) \qquad (8)$$

where

B_T = true regression coefficient of annoyance on the noise index variable

B_o = observed regression coefficient (calculated from the study sample)

σ_o^2 = observed variance of the index variable across the whole sample

σ_e^2 = error variance in the index variable, e.g., the variance of the noise estimates at one location which would be found if the measurements were repeated at that location.

A very extreme example is provided by the data in figure 2 where annoyance is plotted by measured noise level with a slope of $B = 0.57$ and by the corrected noise level with a much steeper slope of $B = 2.85$. (Corrections were made to the original data using the method of instrumental variables (ref. 18)). This involves a regrouping of respondents by a third variable. Clearly, imprecision in the index factor data can seriously bias the estimates of the noise index factor corrections.

All surveys cannot be designed to give perfect estimates of the noise level or of the other index factors' values. The surveys must be designed, however, so that the precision of the estimates of the index factor's data is known. With adequate information about the variability of the data, corrections (such as the one in equation 8) can be applied to give unbiased estimates of study statistics.

Precise estimates of values of the noise index correction.- It was noted earlier that a study's estimate of the noise index correction terms is of little value unless the policymaker can place some confidence in the likelihood that these corrections estimated from the sample are quite close to the true values in the population. In statistical terms, for a factor "F," the ratio B_F/B_L should have a narrow confidence interval, i.e., $\sigma^2_{B_F/B_L}$ must be sufficiently small. A successful study design must maximize the precision of these estimates.

A study should only be conducted if the study design can be expected to meet specified precision goals. Some of the conditions which will minimize $\sigma^2_{B_F/B_L}$ can be identified by examining the formula for $\sigma^2_{B_F/B_L}$ (ref. 19):

$$\sigma^2_{B_F/B_L} = \frac{1}{B_L^2}\left\{\sigma^2_{B_F} - 2\left(\frac{B_F}{B_L}\right)\sigma_{B_FB_L} + \left(\frac{B_F}{B_L}\right)^2\sigma^2_{B_L}\right\} \qquad (9)$$

where

the variance of the partial regression coefficient for factor "F" is:

$$\sigma^2_{B_F} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L\sigma^2_F - (\sigma_{LF})^2}\right) \cdot \sigma^2_L \qquad (10)$$

the variance of the partial regression coefficient for noise level is:

$$\sigma^2_{B_L} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L\sigma^2_F - (\sigma_{LF})^2}\right) \cdot \sigma^2_F \qquad (11)$$

the covariance of B_FB_L is:

$$\sigma_{B_FB_L} = \left(\frac{\sigma^2_e}{n} \cdot \frac{1}{\sigma^2_L\sigma^2_F - (\sigma_{LF})^2}\right) \cdot -\sigma_{LF} \qquad (12)$$

σ^2_e = variance of the residuals from the regression of annoyance on noise level and number

n = number of interviews from a simple random sample

σ^2_L = variance of the noise level

σ^2_F = variance of factor "F"

σ_{LF} = covariance of L and F

The partial regression coefficient, B_L, and the ratio, B_F/B_L, are of course the statistics which are being estimated for the noise index and thus are not subject to manipulation. The value of the ratio B_F/B_L does have an effect on the size of the ratio's variance ($\sigma^2_{B_F/B_L}$). This means that a precision goal for the ratio must be set for the worst value of B_F/B_L (worst in terms of its effect on the variance) which could be expected to occur.

To reduce the variance of B_F/B_L, it is necessary to minimize the variances $\sigma^2_{B_N}$ and $\sigma^2_{B_F}$, and the covariance, $\sigma_{B_L B_F}$. This can be done in five ways:

1. Increase σ^2_L by increasing the range of the noise levels included in the sample or by not heavily sampling at intermediate noise levels.

2. Increase σ^2_F by increasing the range of the values for the index factors.

3. Decrease σ_{LF} by selecting study sites from sample strata which reduce the correlation between noise level and all other noise index variables.

4. Increase "n" by increasing the number of interviews and the number of study areas.

5. Reduce σ^2_e by using precise annoyance measures and precise noise measures.

The reduction due to the first three sources of variation can be readily calculated when a project is designed. The greatest difficulty may be in finding situations in which the various independent variables are not highly correlated.

The reduction in variance which can be expected from increasing the number of interviews and study sites is not known for typical noise survey designs. The effect of the sample size "n" in the formula presented above is appropriate only for simple random samples. With highly clustered samples, characteristic of noise surveys, it can be certain that the effective sample size will be considerably less than the number of interviews. It is also certain that if other aspects of a survey's methodology remain unchanged, more study areas will increase the precision of the estimates. There is both theory and data available on this general sample design problem (ref. 12). For noise surveys in particular, however, data have not yet been analyzed to determine the relative efficiency of increasing the number of interviews as opposed to increasing the number of study areas.

The last way in which estimates can be improved is by reducing σ^2_e ; the unexplained variance in annoyance responses. While errors in the physical noise data could have some effect on σ^2_e , most of the variability is probably due to variability in the recorded human responses. This variability is partly due to the imprecision of the questionnaire measures of human response and partly due to real differences in people's responses to the same noise level.

One way to increase the precision of the corrections is to select annoyance measures which will yield smaller variances for B_F/B_L. For both the 1967 Heathrow survey and the British railway survey, it has been found that multi-item scales yield more precise estimates than simple dichotomies (percent highly annoyed) of single questions. In one example from the railway survey, it was found that a seven-item activity index and a dichotomous "very" annoyed measure (ref. 6) both gave the same value for the number of noise event correction (B_F/B_L = 15). However, the standard deviation for the dichotomy was two and one-half times greater than that for the multi-item index (a 95 percent confidence interval of ±20 for the dichotomy vs. ±8 for the seven-item index). It should be noted that this discussion is directly relevant to the issue of choosing the best annoyance questions and annoyance indices. If all else is equal, the best annoyance scale will be the one which creates the smallest variances for the correction ratios, B_F/B_L. This may not be the most "reliable" annoyance scale as measured by standard reliability coefficients.

Apart from any effects an annoyance measure has on the precision of the regression estimates, the choice of annoyance questions is also important if it affects the value of the noise index corrections. If different annoyance questions do yield different index corrections, it is especially important that surveys include measures of human impact which can be publicly defended as a basis for noise policy. Similarly, the possibility that different questions could give different estimates supports the case for sharing at least one question across noise surveys.

Probability sampling for inductive statistics.- The inductive statistics which are used to calculate the variances discussed above are based on a statistical theory which assumes that probability sampling techniques have been used to draw the sample of study sites as well as the sample of individuals. Any other procedure leaves open the possibility that the investigator unintentionally affects the outcome of the study through his selection of study sites. If probability samples are not used, it must be assumed that the ratios of the partial regression coefficients do not differ systematically between individuals or study areas. There are no published tests of the validity of this assumption for noise surveys. Some noise survey investigators have felt they had to make this assumption because of the mistaken belief that it would be impossible to design a probability sample which would provide the types of study areas required for an analytical study design. In fact, complex probability sample designs can cluster residences around noise measurement points and maintain exact control over the numbers of study sites and respondents from each type of acoustical and nonacoustical environmental situation (refs. 12, 20). Probability sampling gives the policymaker assurance that the study results will be relevant for the population which will be affected by the policy.

NOISE IMPACT ASSESSMENT

Local community noise surveys do not usually attempt to derive noise indices. The major goal for many local surveys is to assess the impact of noise in a particular community. When reduced to the essentials, noise impact assessment consists of statements of the form:

"x" number (or percentage) of people living within area "y" would report that they are impacted by noise in way "z."

There are two critical requirements for this statement: (1) a study questionnaire item which will define the impact and (2) a method of relating sample results to the total population impacted. Each of these will be discussed in turn.

Selection of questionnaire items for impact assessment.- The questionnaire item requirement is quite simple: a question must be used which the policymaker can directly quote as an indicator of the impact of the noise. Most surveys do contain some questions which make it possible to measure impact in terms of the number of people reporting they are:

"annoyed by the noise,"
"very annoyed by the noise,"
"so annoyed by the noise that they would like to move."

Useful, but underutilized types of impact statements can provide direct, meaningful indicators of the frequency with which certain activities are disturbed·

On an average night, "x" number of people will have their television interrupted at least once by noise source "a."

In a year, "x" number of people will have difficulty getting to sleep at least once because of noise source "a."

Comparative statements such as the next two can also be useful:

In an average week, "x" number of people are awakened by noise source "a," but only "y" number of people are awakened by noise source "b."

The number of people startled at least once a week by noise source "a" has increased/decreased by "x" in the 10 years between the two noise surveys.

Most noise surveys have not provided these types of directly useful descriptions of noise impact on activities. Instead, the frequency of activity interference is described in imprecise terms such as "often" or "ever" which are not useful for impact statements.

Success in choosing a noise impact question requires inputs from both the policymaker and the survey researcher. The policy maker can best judge which particular question will be accepted in the policymaking process as a satisfactory measure of noise impact. The survey researcher can judge whether questions can be easily understood by respondents. He can draw on past experience with noise questions to indicate types of questions which may give misleading results. The following example of such a misleading question suggests the importance of technical expertise in the area.

The question of whether people are "used to" or are "able to live with" noise might seem to the policymaker to be a useful indicator of whether the noise level is acceptable to the population. In a reanalysis of the Phase II TRACOR aircraft noise survey, it has been found that 75 percent of the sample reported they could "live with" the aircraft noise. (The TRACOR survey is described in ref. 21.) However, when the responses of these people who could "live with" the noise were examined in more detail, it was found that the aircraft noise was not acceptable to them; 52 percent reported they were "very" or "extremely" bothered by radio or TV watching being disturbed by aircraft, 63 percent had their conversations interrupted, and 35 percent were disturbed when trying to go to sleep. Questions about being able to "live with" a noise thus are not well suited for use in noise impact assessment because the apparent meaning to a casual observer (that people who can "live with" a noise would find it acceptable) is not the actual meaning to the respondents (that people who have found it possible to "live with" a noise still find it highly annoying).

It should be apparent that the annoyance measurement requirements are different for these noise impact statements than for the earlier noise index analyses. For noise impact questions, simple quotable questions are needed. For the noise index definition task, more precise annoyance measures are needed even if they involve combinations of scales into indices without simple definitions of the scale points.

Sampling for noise impact assessment.- In addition to a useful questionnaire measure of noise impact, a noise impact assessment statement must also link a study sample's characteristics to the population's characteristics. For a noise impact statement, there is no interest in the sample itself. The interest is in the information which the sample can provide about the population. The percentage of the sample which is impacted is mainly a function of sample design decisions about the noise levels at which the sample would be concentrated. Surveys can make only two types of statements (depending on their sample design):

1. "Some" nonzero number of people are impacted. (This statement can always be made if some sample members are impacted.)

2. Between "x" and "x+a" people in a population of interest are estimated with a known probability, (e.g., 95 percent confidence interval) to be impacted. (This statement can be made if a probability sample is drawn from a defined area.)

The first statement only establishes that there is some annoyance but does not provide information with any calculable certainty as to the number of people impacted. The information can, however, be collected during a short time period, with almost no advanced planning and without professional statistical assistance.

The second type of statement requires a probability sample based on specialized statistical sampling techniques. In addition to describing the overall present situation, surveys based on probability samples make it possible to make statements with known levels of certainty about differences between reactions in different areas, changes in noise impact over time, and the importance of particular noise problems relative to other environmental problems. Here are three useful noise impact statements based on probability samples:

In the United States in 1977, 5.8 million people ±0.2 million (95 percent confidence interval) would have said they were "at least a little bothered" by aircraft noise. (ref. 22).

After 15 years, surveys did not find large or statistically significant changes in the percentage of the population within the 10 mile area around Heathrow airport who said that aircraft noise is the single thing they would most like to change: 7 percent in 1961; 6 percent in 1967; 8 percent in 1976. (refs. 23, 2, 24)

In 1972 in England, the streets on which people reside would have been described as "quiet" by 60 percent, ±2 percent, of the residents (95 percent confidence interval). (Based on reanalysis of study described in ref. 25.)

Of 120 community noise surveys which included information about the sample design, only 10 used probability sampling techniques to select both the study areas and respondents. Some of these surveys had primarily analytical goals and were willing to make the assumptions discussed earlier. However, it is clear that probability samples have been under utilized. There are some indications that they are beginning to be used more. The EPA model community noise survey handbook (ref. 26) recommends a probability sample and provides a detailed description of how such a sample can be drawn for simple descriptive community surveys.

The basic point on sample selection is quite simple. If a policymaker wishes to only establish that noise bothers "some" people, then a nonprobability sample will be adequate. If even moderate resources are to be invested, then the use of a probability sample will make it possible to make much more powerful noise impact assessment statements.

CONCLUDING REMARKS

After examining reports from a large number of social surveys, two areas have been identified where methodological improvements in the surveys would be especially useful for public policy. The two study areas are the definition of noise indices and the assessment of noise impact.

Multiple regression analysis is a useful technique for the noise index definition task because it provides direct estimates of the correction terms in noise indices. Multiple regression analysis also provides a convenient framework for considering the assumptions which are implicit in noise index models.

The validity and reliability of surveys' estimates of the noise indices' correction terms will be increased if (1) surveys are designed to meet specific accuracy goals, (2) objective measurements are made of both acoustical and nonacoustical environmental factors, (3) the precision of studys' measurements of the noise index factors (including noise level) is known, (4) observations are spread over a wide range of values for each index factor, (5) the index factors are not highly correlated in sample designs, (6) precise measures of annoyance are used, (7) large numbers of interviews and study areas are included, (8) probability sample designs are adopted, and (9) some noise impact questions are shared between surveys.

Community surveys can better assess noise impact if (1) questionnaires include questions which can be directly quoted to evaluate noise impact and (2) probability samples are drawn from well-defined populations.

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APPENDIX

The index based on observers' ratings of the environmental quality is created by averaging together five ratings of aspects of the visual quality of the neighborhood. The aspects of the neighborhood used are: upkeep of buildings (two observations), upkeep of front gardens (yards), landscaping of area, and rating of sizes of homes and gardens. Each aspect was rated by an observer using a precoded, descriptive classification scheme. The ratings for each aspect were then given a score between zero (for the poorest environment) to three (for the best environment). These scores were averaged and only the value of the units digit was retained. For the dichotomous scale used in this paper, the upper category (25 percent of the sample) was rated as being in a high quality neighborhood environment.

The measure of the perception of the area is similar to that used by other researchers. The question asks how satisfied the respondent is with "this area as a place to live in." Those who said they were very satisfied (44 percent of the sample) are coded as "high" on the respondent's neighborhood rating measure in the text.

A complete description of the indices' definitions can be found in the final British railway study report (ref. 27).

FIGURE 1 .- RAILWAY TRACTION TYPE EFFECT

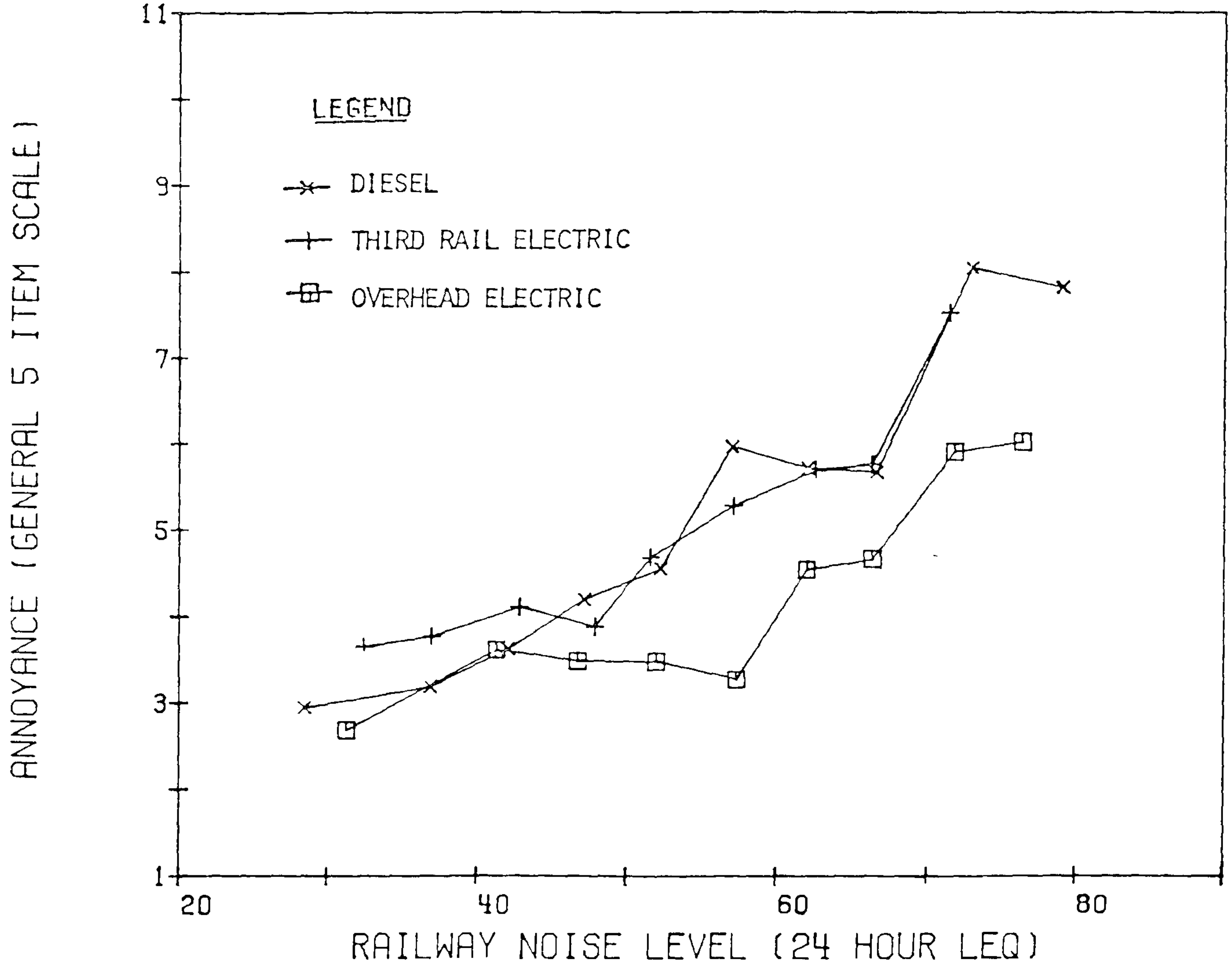
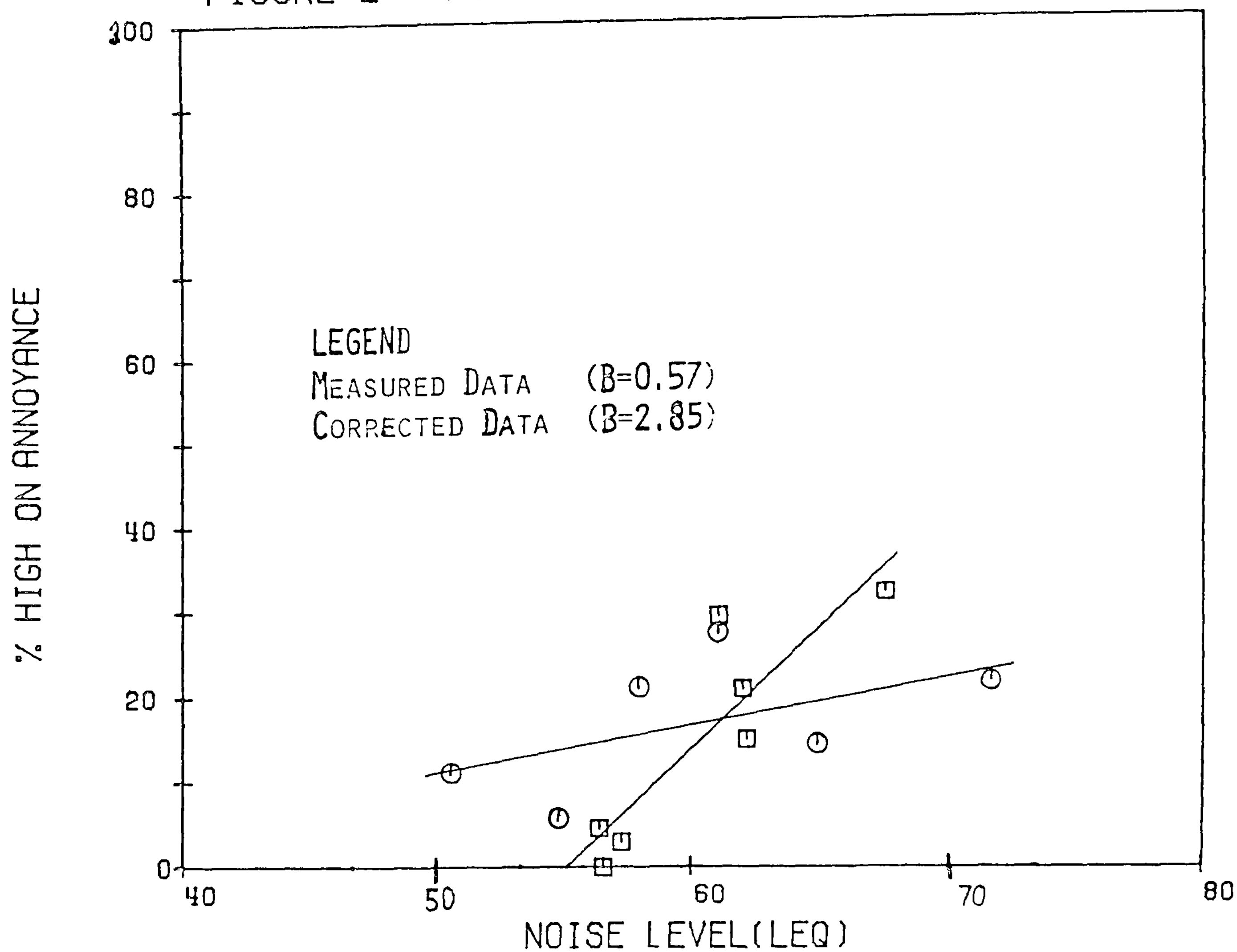


FIGURE 2.- NOISE MEASUREMENT PRECISION



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