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EVALUATION OF NOISE POLLUTION LEVEL BASED UPON COMMUNITY EXPOSURE AND RESPONSE DATA

By Richard D. Edmiston

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TRACOR, Inc.
Austin, Texas
for
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1.0 SUMMARY

In this report, Noise Pollution Level (L_{NP}) is evaluated as a measure of human response to aircraft noise. Comparison with the formulations of traditional exposure measures (CNR, NEF, and NNI) and with the Traffic Noise Index (TNI) indicates that for aircraft noise, it is easier to estimate CNR, NEF and NNI accurately, but easier to actually measure L_{NP} and TNI.

L_{NP} values for daytime, nighttime, and 24-hour periods were calculated for the 2912 respondents of a previously conducted survey. Comparison of CNR and L_{NP} as linear predictors of individual response to aircraft noise shows that CNR is slightly superior to any combination of L_{NP}(Day) and L_{NP}(Night) and to L_{NP}(Total) when only acoustical variables are used as predictors. When social psychological variables are added to the linear prediction models the same result holds, but the differences are generally smaller. Using a nonlinear regression model, L_{NP}(Day), L_{NP}(Night), and social variables predict individual annoyance slightly better than CNR with the same social variables.

L_{EQ} is the energy-mean sound level and σ is the standard deviation in level, both being components of L_{NP}. The set of variables $\{L_{EQ}(\text{Day}), \sigma(\text{Day}), L_{EQ}(\text{Night}), \sigma(\text{Night})\}$ affords better prediction than CNR, L_{NP}(Day), L_{NP}(Night), or L_{NP}(Total) in every case, but the coefficients derived from the data for these terms are contradictory to the L_{NP} formula and may be questionable because of the high degree of correlation between these variables.

As predictors of mean or median annoyance of a population exposed to known ranges of noise exposure, CNR, L_{NP}(Day), L_{NP}(Night), and L_{NP}(Total) are all excellent.

2.0 INTRODUCTION

This report presents the results and procedures from an evaluation of Noise Pollution Level as a predictor of annoyance, based upon aircraft noise exposure and community response data, under Contract NASW-2304. The period of performance is 7 September 1971 to 30 April 1972.

In 1970 TRACOR completed a three-year study of community reaction around seven major U.S. airports (Contract NASW-1549). This study is generally referred to as "the seven-city study." In this research considerable insight was gained into the interrelationships of noise exposure, annoyance, complaint, and individual attitudes and characteristics. Additional information was obtained concerning noise monitoring techniques, the relationships between different measures of community noise exposure, and the effect of house attenuation. Phase I of this program included collection of data from Dallas, Chicago, Denver, and Los Angeles, while Phase II involved the cities of New York, Boston, and Miami. A multivariant equation for predicting individual annoyance was derived in the first phase of work and tested in the second phase.

The seven-city report analyzed several measures of noise exposure, including Composite Noise Rating (CNR) (Bolt, Beranek and Newman, 1964), Noise Exposure Forecast (NEF) (Bishop et al, 1967), and the Noise and Number Index (NNI) (Wilson, 1963). While Phase II of this study was in progress, D. W. Robinson proposed Noise Pollution Level (L_{NP}) as a new measure of composite noise exposure (Robinson, 1969). This new measure is proposed as a "universal" noise exposure measure, and Robinson's paper indicates favorable results from the use of L_{NP} with data from several human response studies previously performed. A recent DOT study (Serendipity, 1971) found similar results.

The relative simplicity of L_{NP}, when used for measurement of actual exposure, makes it a very attractive index. The Department of Transportation in particular has expressed interest in the validation of the L_{NP} concept. In order to investigate the validity of L_{NP} as a measure of aircraft noise exposure, TRACOR proposed to the National Aeronautics and Space Administration to calculate L_{NP} values for each of the respondents in Phase II of the seven-city program and to evaluate L_{NP} as a predictor of human response. This report documents the resulting study.

3.0 COMPUTATIONAL SIMPLICITY OF NOISE EXPOSURE MEASURES

There exist many different techniques for evaluating composite noise exposure. Each of these measures has advantages and disadvantages. Noise Pollution Level (L_{NP}), the subject of this report, has been proposed as a universal measure, whereas historically noise exposure measures have been developed to predict human response to noise from a particular source. In this country, the Composite Noise Rating (CNR) and the Noise Exposure Forecast (NEF) were developed to assess human response to the composite noise exposure experienced near an airport. In the United Kingdom, a similar measure called the Noise and Number Index (NNI) was developed for the same purpose. The Traffic Noise Index (TNI), also developed in the United Kingdom, is used to predict human response to road traffic noise.

In order to compare the computational simplicity of these measures, it is necessary to point out fundamental differences between them and to examine the way in which such measures are generally used. The fundamental differences include the weighting functions used to approximate human subjective response and the portion of the total acoustic signal used for calculation of the exposure measure. The two primary uses of these measures are prediction of exposure and measurement of actual exposure.

3.1 Filter Functions and "On" Time

CNR and NEF are both historically derived from extensive psychophysical investigations into judged human responses of the noisiness of complex sounds. In their strictest forms, they require octave band and one-third octave band (respectively) spectral analyses to be performed on the acoustical stimulus. CNR can be calculated from a single spectrum, but NEF requires a time series of spectra and discrete frequency and duration corrections. Recent results, however, indicate that a suitable analog filter similar to an A- or N-weighting network may provide as accurate predictions of human judgments as the elaborate spectral analysis specified originally. In any case, the acoustic input for these measures is analyzed during flyovers only. Both CNR and NEF treat night operations by addition of a constant to the flyover Perceived Noise Level (PNL), and both combine multiple flyovers on the basis of energy addition. NNI, as originally defined, treats individual daytime flyovers exactly as CNR does, but, in practice, the perceived noise level was calculated using an N-weighting network, rather than from octave band analysis. Day and night operations are kept separate, yielding NNI_D and NNI_N, and multiple operations are summed on the basis of 15 $\log_{10} n$. TNI is obtained from the statistical distribution of A-weighted sound levels, the important parameters being the levels exceeded 90 percent of the time (L_{90}) and 10 percent (L_{10}). The level distribution analyzed is for a complete 24-hour sample period, regardless of whether a particular type of noise source was present or not. L_{NP} may be measured using any accepted filter function, as long as it is specified. The calculation of L_{NP} is similar to that of TNI in that it also uses the complete statistical distribution of levels, but the relevant statistics in this case are the energy mean level (L_{EQ}) and the standard deviation of these levels (σ or ST DEV). Day and night periods are to be treated separately.

3.2 Prediction of Exposure

As a result of their historical development, the exposure measures CNR and NEF have been used primarily for prediction of exposure resulting from aircraft flyovers in areas near airports. NNI, which was originally developed from empirical physical data, is easily calculable from the same data required for the calculation of CNR. The basic requirement for the calculation of any of these three measures is a knowledge of the distribution of PNL values for daytime and nighttime operations at a given location, where it is assumed that each data point represents a complete flyover, and that the total number of flyovers is implicit in the distribution of levels. Both TNI and L_{NP} require considerably more knowledge of the acoustical environment than the previous measures. In the case of TNI, it is necessary to be able to estimate L_{10} and L_{90} for a complete "average" day. Considerable progress has been made in estimating these parameters when the major noise source is highway noise (Serendipity, 1971), but the corresponding treatment for aircraft noise has not yet been developed. The same problems exist in the prediction of L_{NP} in the case of aircraft noise. Appendix A describes the method used for calculating L_{NP} values for this report. The assumptions and procedures described there could be modified to calculate TNI. These calculations require (1) all the information necessary to calculate CNR; (2) information on the time duration of flyovers for each type of aircraft and for each flight path; and (3) estimates of the median background noise level in the absence of aircraft overflight. For the present study, these data were supplied by the acoustical survey conducted in conjunction with the social survey.

In summary, all of the necessary tools exist and are well documented for the calculation of CNR, NEF, or NNI in the vicinity of an airport. In order to predict TNI or L_{NP} near an airport, data are required in addition to those required for the first three measures.

3.3 Measurement of Exposure

The requirements for measurement of composite noise exposure are very different from the requirements for prediction of exposure. In the measurement case, the measures TNI and L_{NP} are much simpler than CNR, NEF, or NNI. The first two measures can be calculated from data gathered by simple monitoring equipment and analyzed by statistical distribution analyzers, or in equivalent fashion. The monitoring equipment is relatively inexpensive and very simple to automate. To correspond to the original definition of the latter three aircraft noise measures, however, it is necessary for the monitoring equipment to discriminate aircraft noise from that of other sources as well as to perform the calculations necessary for the particular measure being used. Use of frequency weighting networks for these measures can circumvent the spectrum analysis problem, but separation of aircraft noise from that of other noise sources such as motor vehicles or children playing is presently not possible with an unattended monitor. NEF or CNR may be generalized to allow a device which integrates all noise samples during the daytime and the nighttime periods. It is clear, however, that such a procedure would yield values numerically greater than those produced by the standard algorithms in areas with low aircraft overflight exposure levels.

The discussion of measurement techniques above is based entirely upon consideration of aircraft noise exposure. Discussion of the use of the various measures as indices of general noise exposure is beyond the scope of this report. It is clear on casual examination of the history of the various measures, however, that the aircraft noise exposure measures CNR, NEF, and NNI were developed as descriptors of discrete event noise exposure. Use of these measures as descriptors of noise which is by nature non-discrete (i.e., where no single source dominates the level for an easily definable period of time) is not consistent with their original purpose and has not been validated.

3.4 Selection of an Exposure Measure

From purely practical considerations, the discussion of the preceding sections indicates that

(1) For prediction of exposure from aircraft where actual measurements are impractical, one of the existing aircraft noise measures CNR, NEF, or NNI should be used.

(2) For large-scale measurement programs where monitors must be unattended L_{NP} or TNI should be used.

As more is learned about TNI and L_{NP} it may become practical to use these measures for both prediction and measurement. From the discussion in Appendix A it can be seen that L_{NP} is very sensitive to assumptions made regarding the distribution of background levels. The accuracy of current estimating procedures for L_{10}, L_{50}, and L_{90} must be evaluated in more detail, and sensitivity analyses should be performed to determine the effects on L_{NP} of the uncertainties in estimation procedures.

In connection with the next section of this report, it should be mentioned that for prediction of reaction to aircraft noise the measure L_{EQ} performed about as well as CNR or L_{NP}. Since L_{EQ} is easier to measure or to predict than any of the five measures discussed above, further investigation into its use seems warranted.

4.0 ANALYSIS

The fundamental objective of this study is to assess the ability of L_{NP} to predict an individual's annoyance due to the noise of aircraft operations. This section describes the data base available for use in this study, the dependent and independent variables developed from that data base, the use of these variables to predict individual annoyance, and finally, the ability of the acoustical variables to predict average annoyance.

4.1 Data Base

Data gathered from extensive random sample interviewing in Boston, Miami, and New York in the summer of 1969 were used as the basis for the L_{NP} evaluation. There was a total of 2912 respondents, with 1166 in Boston, 676 in Miami, and 1070 in New York. The data were in the form of seven-card decks of sociometric and acoustical measurements. More detailed information about content is contained in a previous report (TRACOR, 1970).

The acoustical data used to compute L_{NP} were measurements of ambient level, number of flyovers, duration of flyovers, and distributions of maximum Perceived Noise Levels. Boston had 16 census tracts out of 66 with on-site direct measurements; Miami, 15 out of 40; and New York, 22 out of 71. The remaining census tracts were assigned extrapolated values. A total of 5765 flyovers were measured for the entire sample, with 1911 in Miami, 1697 in Boston, and 2157 in New York.

4.2 Dependent and Independent Variables

The following social variables, derived from answers to the questionnaire duplicated in Appendix B, were found in the earlier TRACOR study to be the best measures or predictors of annoyance (TRACOR, 1970). Appendix C explains the detailed construction of these variables.

Annoyance G, the dependent variable, is a measure of disturbance of everyday activities, and the annoyance caused by that disturbance.

Noise Susceptibility is a measure of the number of common noise sources the respondent hears, and the degree to which each annoys him.

Fear is a measure of the respondent's fear of aircraft crashing in his neighborhood.

Adaptability is a measure of the respondent's willingness to tolerate more noise exposure from aircraft than he is now receiving.

Misfeasance measures the respondent's belief that those officials and authorities who are in a position to do something about the noise problem are not doing their job.

Importance is a measure of the respondent's attitude toward the airport and toward aviation in general. A high score indicates that the respondent does not feel aviation services are important to his community or the nation.

Distance is a measure of the straight-line distance from the respondent's home to the end of the nearest runway.

The following acoustical variables are used independently or in combination as predictors of annoyance.

CNR is the Composite Noise Rating described in "Land Use Planning" (Bolt, Beranek and Newman, Inc., 1964), but constructed as a continuous variable rather than in 5-unit steps.

L_{NP} is the Noise Pollution Level as defined by Robinson (1969). L_{NP} is expressed as

$$L_{NP} = L_{EQ} + 2.56\sigma$$

L_{EQ} is the energy mean level of a distribution of levels for a given time period.

σ is the standard deviation (ST DEV) of this same distribution of levels, defined in the normal statistical sense.

Robinson defines L_{NP} for particular periods of the day. Therefore in this report each of the last three measures is suffixed with one of the terms: Day, Night, or Total. The suffix "Day" means that the distribution of levels observed between 7:00 a.m. and 10:00 p.m. local time was used to compute the measure. The suffix "Night" refers to the distribution for the time period from 10:00 p.m. and 7:00 a.m. The suffix "Total" refers to the entire 24-hour day. Appendix A describes the computation of L_{NP}, L_{EQ}, and σ from the available data base.

4.3 Prediction of Individual Annoyance

One metric widely accepted for use in evaluating noise exposure measures is the ability of a given measure to predict individual annoyance (where it is implicitly assumed that annoyance implies an unfavorable attitude toward noise). Two mathematical prediction models which have been utilized are linear regression analysis and multiple classification analysis.

Because Robinson does not give a procedure for combining day and night noise exposure into a single measure, it was necessary to treat L_{NP}(Day), L_{NP}(Night), and L_{NP}(Total) as independent variables. In addition, each of the components of L_{NP} (L_{EQ} and σ for Day, Night, and Total periods) was treated in the analysis procedure. CNR was analyzed for comparison with the L_{NP} measures and to provide means for comparison of L_{NP} and other acoustical measures which have been related to CNR in previous analyses (TRACOR, 1970). Table 1 shows the correlation coefficients between individual annoyance and various noise exposure parameters. It can be seen that the correlation between any noise exposure measure and annoyance is in the range of 0.36 to 0.43, while the noise exposure parameters correlate among themselves in the range of 0.87 to 1.0 (excluding ST DEV measures in both instances).

It is well known that the inclusion of social and attitudinal variables improves the ability of a regression model to predict individual annoyance. For this reason, the regression models were run both with and without social variables. Table 2 gives the correlations between annoyance, social variables, and basic noise exposure measures.

TABLE 1

CORRELATIONS BETWEEN INDIVIDUAL ANNOYANCE AND VARIOUS NOISE EXPOSURE PARAMETERS

	ANNOYANCE	CNR	L_{EQ} (Day)	L_{EQ} (Night)	L_{EQ} (Total)	L_{NP} (Day)	L_{NP} (Night)	L_{NP} (Total)	ST DEV (Day)	ST DEV (Night)	ST DEV (Total)
ANNOYANCE	1.000	0.434	0.393	0.431	0.400	0.359	0.399	0.360	0.215	0.275	0.191
CNR	-	1.000	0.930	0.968	0.938	0.868	0.919	0.873	0.553	0.671	0.513
L_{EQ}(DAY)	-	-	1.000	0.972	0.999	0.935	0.925	0.933	0.600	0.682	0.555
L_{EQ}(NIGHT)	-	-	-	1.000	0.980	0.912	0.964	0.919	0.588	0.732	0.551
L_{EQ}(TOTAL)	-	-	-	-	1.000	0.934	0.936	0.934	0.598	0.694	0.554
L_{NP}(DAY)	-	-	-	-	-	1.000	0.946	0.998	0.884	0.841	0.811
L_{NP}(NIGHT)	-	-	-	-	-	-	1.000	0.960	0.738	0.887	0.719
L_{NP}(TOTAL)	-	-	-	-	-	-	-	1.000	0.844	0.863	0.815
ST DEV(DAY)	-	-	-	-	-	-	-	-	1.000	0.869	0.995
ST DEV(NIGHT)	-	-	-	-	-	-	-	-	-	1.000	0.885
ST DEV(TOTAL)	-	-	-	-	-	-	-	-	-	-	1.000

TABLE 2

CORRELATIONS BETWEEN ANNOYANCE - RELATED VARIABLES AND BASIC NOISE EXPOSURE MEASURES

	ANNOYANCE	FEAR	ADAPTABILITY	SUSCEPTIBILITY	MISFEASANCE	IMPORTANCE	DISTANCE	CNR	L_{EQ}(Total)	L_{NP}(Total)
ANNOYANCE	1.000	0.615	-0.446	0.388	0.386	0.375	-0.137	0.434	0.400	0.360
FEAR	-	1.000	-0.397	0.320	0.302	0.312	-0.181	0.374	0.356	0.319
ADAPTABILITY	-	-	1.000	-0.182	-0.228	-0.234	0.105	-0.262	-0.235	-0.210
SUSCEPTIBILITY	-	-	-	1.000	0.231	0.188	-0.017	0.080	0.070	0.049
MISFEASANCE	-	-	-	-	1.000	0.489	-0.039	0.201	0.181	0.152
IMPORTANCE	-	-	-	-	-	1.000	-0.094	0.245	0.241	0.217
DISTANCE	-	-	-	-	-	-	1.000	-0.438	-0.464	-0.472
CNR	-	-	-	-	-	-	-	1.000	0.938	0.873
L_{EQ}(Total)	-	-	-	-	-	-	-	-	1.000	0.934
L_{NP}(Total)	-	-	-	-	-	-	-	-	-	1.000

4.3.1 Linear Regression with Acoustical Variables - Linear regression analysis fits the best N-dimensional straight line through the data such that the following equations best predict Annoyance G in a least squares sense:

$$A = \sum_{i=1}^{N} b_i X_i + K$$

$$a = \sum_{i=1}^{N} \beta_i x_i$$

where A = predicted value of Annoyance G

X_i = raw score value of variable i

b_i = raw score weight for variable i

K = regression constant

a = predicted standard score for Annoyance G

x_i = standard (z) score for X_i

β_i = standard score weight (beta weight) for variable i

N = number of predictor variables

To examine the ability of L_{NP} to predict annoyance without social variables, a linear regression analysis was performed. This procedure determines the best values of the b_i, K, and β_i of the previous equations in the sense described. Table 3 shows the beta weights of each of the sixteen sets of variables used for linear regression analysis. The first ten columns are for single-variable predictors, and the last six columns are for various reasonable combinations of acoustical variables. The beta values are equivalent to the correlation coefficients between the acoustical variables and annoyance. The next-to-last entry in each column is the square of the multiple regression correlation coefficient, and is a measure of the amount

TABLE 3

LINEAR REGRESSION OF ANNOYANCE G ON ACOUSTICAL VARIABLES

PREDICTORS (x_i)	STANDARD SCORE WEIGHTS (β_i)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CNR	0.434	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_{NP}(Day)	-	0.359	-	-	-	-	-	-	-	-	-0.186	-	-	-	-	-
L_{NP}(Night)	-	-	0.400	-	-	-	-	-	-	-	0.576	-	-	-	-	-
L_{NP}(Total)	-	-	-	0.360	-	-	-	-	-	-	-	-	-	-	-	-
L_{EQ}(Day)	-	-	-	-	0.393	-	-	-	-	-	-	-0.712	-0.469	0.412	-	-
L_{EQ}(Night)	-	-	-	-	-	0.431	-	-	-	-	-	1.234	0.887	-	0.494	-
L_{EQ}(Total)	-	-	-	-	-	-	0.400	-	-	-	-	-	-	-	-	0.424
ST DEV (Day)	-	-	-	-	-	-	-	0.215	-	-	-	0.155	-	-0.032	-	-
ST DEV (Night)	-	-	-	-	-	-	-	-	0.275	-	-	-0.276	-	-	-0.086	-
ST DEV (Total)	-	-	-	-	-	-	-	-	-	0.191	-	-	-	-	-	-0.044
Multiple R	0.434	0.359	0.400	0.360	0.393	0.431	0.400	0.215	0.275	0.191	0.404	0.454	0.444	0.394	0.435	0.401
Multiple R^2	0.188	0.129	0.160	0.130	0.155	0.185	0.160	0.046	0.076	0.037	0.163	0.209	0.197	0.155	0.189	0.161
R^2 Rank	4	13	8.5	12	10.5	5	8.5	15	14	16	6	1	2	10.5	3	7

of variability in the data which is explained by the associated regression equation. This explained variance ranges from a low of 3.7% for Column 10 to a high of 20.9% for Column 12. The last entry in each column is the rank of R^2 for that column among the sixteen columns.

The standard score weights in Table 3 indicate the contribution of each acoustical variable toward the prediction of Annoyance G. Table 4 presents the raw score weights and regression constants necessary for the calculation of Annoyance G directly from raw score data. The last two entries in each column are repeated from Table 3.

TABLE 4

LINEAR REGRESSION OF ANNOYANCE G ON ACOUSTICAL VARIABLES

PREDICTORS (X_i)	RAW SCORE WEIGHTS (b_i)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
CNR	0.577	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_{NP}(Day)	-	0.457	-	-	-	-	-	-	-	-	-0.237	-	-	-	-	-
L_{NP}(Night)	-	-	0.410	-	-	-	-	-	-	-	0.591	-	-	-	-	-
L_{NP}(Total)	-	-	-	0.461	-	-	-	-	-	-	-	-	-	-	-	-
L_{EQ}(Day)	-	-	-	-	0.747	-	-	-	-	-	-	-1.353	-0.892	0.783	-	-
L_{EQ}(Night)	-	-	-	-	-	0.652	-	-	-	-	-	1.868	1.343	-	0.747	-
L_{EQ}(Total)	-	-	-	-	-	-	0.734	-	-	-	-	-	-	-	-	0.779
ST DEV (Day)	-	-	-	-	-	-	-	1.593	-	-	-	1.146	-	-0.235	-	-
ST DEV (Night)	-	-	-	-	-	-	-	-	1.854	-	-	-1.862	-	-	-0.581	-
ST DEV (Total)	-	-	-	-	-	-	-	-	-	1.456	-	-	-	-	-	-0.335
Regression Constant	-44.2	-25.3	-18.3	-27.4	-38.1	-27.2	-36.2	6.3	4.5	4.6	-11.8	-4.6	-7.98	-38.98	-29.4	-36.2
Multiple R^2	0.188	0.129	0.160	0.130	0.155	0.185	0.160	0.046	0.076	0.037	0.163	0.209	0.197	0.155	0.189	0.161
R^2 Rank	4	13	8.5	12	10.5	5	8.5	15	14	16	6	1	2	10.5	3	7

4.3.2 Linear Regression with Social and Acoustical Variables - Linear regression analyses were performed using acoustical variables in conjunction with the social variables described in Section 3.2. In addition, one analysis was performed with social variables only. The results of these analyses are presented in Tables 5 and 6, giving standard and raw score weights respectively. Examination of the multiple R^2 values for each column shows that the social variables by themselves explain almost 50% of the variability of annoyance, while addition of any set of acoustical variables adds no more than 4% to this figure.

TABLE 5

LINEAR REGRESSION OF ANNOYANCE G ON SOCIAL AND ACOUSTICAL VARIABLES

PREDICTORS (x_i)	STANDARD SCORE WEIGHTS (β_i)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Noise Susceptibility	0.172	0.185	0.183	0.185	0.183	0.185	0.185	0.182	0.177	0.180	0.177	0.186	0.185	0.184	0.180	0.186	0.182
Fear	0.407	0.354	0.372	0.365	0.372	0.363	0.353	0.361	0.396	0.389	0.399	0.365	0.347	0.356	0.364	0.355	0.362
Adaptability	-0.197	-0.172	-0.184	-0.178	-0.184	-0.183	-0.176	-0.184	-0.197	-0.189	-0.197	-0.179	-0.173	-0.172	-0.184	-0.173	-0.184
Misfeasance	0.126	0.115	0.124	0.116	0.123	-0.121	0.115	0.117	0.128	0.120	0.128	0.116	0.115	0.110	0.119	0.116	0.117
Importance	0.105	0.085	0.087	0.085	0.087	0.084	0.084	0.087	0.099	0.096	0.101	0.085	0.085	0.088	0.087	0.084	0.087
Distance	-0.025	0.059	0.052	0.041	0.051	0.053	0.056	0.055	0.010	0.007	0.000	0.035	0.055	0.042	0.055	0.056	0.055
CNR	-	0.223	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_{NP}(Day)	-	-	0.177	-	-	-	-	-	-	-	-	-0.062	-	-	-	-	-
L_{NP}(Night)	-	-	-	0.199	-	-	-	-	-	-	-	0.253	-	-	-	-	-
L_{NP}(Total)	-	-	-	-	0.178	-	-	-	-	-	-	-	-	-	-	-	-
L_{EQ}(Day)	-	-	-	-	-	0.191	-	-	-	-	-	-	-0.371	-0.242	0.184	-	-
L_{EQ}(Night)	-	-	-	-	-	-	0.222	-	-	-	-	-	0.627	0.450	-	0.233	-
L_{EQ}(Total)	-	-	-	-	-	-	-	0.197	-	-	-	-	-	-	-	-	0.192
ST DEV (Day)	-	-	-	-	-	-	-	-	0.099	-	-	-	0.099	-	0.014	-	-
ST DEV (Night)	-	-	-	-	-	-	-	-	-	0.129	-	-	-0.137	-	-	-0.018	-
ST DEV (Total)	-	-	-	-	-	-	-	-	-	-	0.086	-	-	-	-	-	0.006
Multiple R	0.705	0.729	0.721	0.726	0.721	0.723	0.729	0.724	0.710	0.714	0.709	0.726	0.734	0.732	0.723	0.729	0.724
Multiple R^2	0.497	0.531	0.519	0.526	0.520	0.523	0.531	0.524	0.505	0.510	0.503	0.527	0.539	0.536	0.523	0.532	0.524
R^2 Rank	17	4.5	13	7	12	10.5	4.5	8.5	15	14	16	6	1	2	10.5	3	8.5

TABLE 6

LINEAR REGRESSION OF ANNOYANCE G ON SOCIAL AND ACOUSTICAL VARIABLES

PREDICTORS (X_i)	RAW SCORE WEIGHTS (b_i)																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Noise Susceptibility	0.278	0.298	0.294	0.299	0.295	0.298	0.298	0.293	0.285	0.291	0.285	0.299	0.299	0.297	0.290	0.300	0.293
Fear	1.791	1.557	1.638	1.605	1.638	1.596	1.554	1.589	1.742	1.711	1.753	1.606	1.528	1.566	1.603	1.563	1.593
Adaptability	-5.777	-5.026	-5.393	-5.227	-5.384	-5.350	-5.159	-5.380	-5.625	-5.548	-5.634	-5.234	-5.068	-5.039	-5.407	-5.059	-5.393
Misfeasance	1.147	1.052	1.135	1.060	0.129	1.106	1.053	1.072	1.170	1.092	1.169	1.061	1.047	1.003	1.088	1.05	1.072
Importance	1.212	0.974	1.000	0.972	1.000	0.969	0.961	1.003	1.142	1.106	1.158	0.973	0.977	1.012	0.998	0.965	1.005
Distance	-0.160	0.380	0.334	0.262	0.327	0.344	0.363	0.357	0.063	0.047	0.	0.229	0.354	0.271	0.359	0.363	0.354
CNR	-	0.297	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_{NP}(Day)	-	-	0.225	-	-	-	-	-	-	-	-	-0.079	-	-	-	-	-
L_{NP}(Night)	-	-	-	0.204	-	-	-	-	-	-	-	0.260	-	-	-	-	-
L_{NP}(Total)	-	-	-	-	0.228	-	-	-	-	-	-	-	-	-	-	-	-
L_{EQ}(Day)	-	-	-	-	-	0.362	-	-	-	-	-	-	-0.705	-0.460	0.349	-	-
L_{EQ}(Night)	-	-	-	-	-	-	0.336	-	-	-	-	-	0.950	0.682	-	0.352	-
L_{EQ}(Total)	-	-	-	-	-	-	-	0.363	-	-	-	-	-	-	-	-	0.351
ST DEV (Day)	-	-	-	-	-	-	-	-	0.734	-	-	-	0.732	-	0.101	-	-
ST DEV (Night)	-	-	-	-	-	-	-	-	-	0.866	-	-	-0.923	-	-	-0.121	-
ST DEV (Total)	-	-	-	-	-	-	-	-	-	-	0.652	-	-	-	-	-	0.044
Regression Constant	3.0	-31.1	-20.7	-16.8	-21.7	-26.3	-22.3	-25.8	-3.9	-4.5	-4.3	-14.1	-10.4	-11.2	-26.1	-22.6	-25.5
Multiple R^2	0.497	0.531	0.519	0.526	0.520	0.523	0.531	0.524	0.505	0.510	0.503	0.527	0.539	0.536	0.523	0.531	0.524
R^2 Rank	17	4.5	13	7	12	10.5	4.5	8.5	15	14	16	6	1	2	10.5	3	8.5

4.3.3 Multiple Classification Analysis - As another model for prediction of annoyance, multiple classification analysis (MCA) was used. This technique affords better prediction in cases where extreme nonlinear dependencies exist. Each predictor variable is categorized, and annoyance is predicted by the sum of the category weights for the categories selected:

$$A = \sum_{i=1}^{N} \sum_{j=0}^{M_i} a_{ij} \, \delta(j, X_i) + \bar{A}$$

where A = Annoyance G

N = number of predictor variables

M_i = number of categories for predictor variable i

a_{ij} = weight for category j of variable i

X_i = raw score of variable i

$\delta(j, X_i)$ = 1, if X_i is in category j
= 0, otherwise

$\bar{A}$ = Mean Annoyance G for total sample

Although MCA is essentially a nonlinear technique, the algorithm computes a pseudo-standard score weight β_i using the following algorithm (Andrews, et al, 1967):

$$\beta_i = \frac{1}{\sigma} \left[\sum_{j=0}^{M_i} n_{ij} \, a_{ij}^2 / n \right]^{\frac{1}{2}}$$

where n = total number of respondents

n_{ij} = number of respondents in category j of variable i

σ = standard deviation of Annoyance G

For this study, MCA was used only as an analytical tool. The beta values presented in Table 7 are directly comparable to the absolute values of the betas presented in Table 5. In general, the results of this analysis are consistent with the results of the linear regression analysis. Some indication was obtained that the partial function of annoyance with respect to standard deviation reaches a peak in the mid-range of observed values of standard deviation, and then decreases as standard deviation increases. This behavior would explain the low beta weights of standard deviation variables when used in linear regression models.

TABLE 7

MULTIPLE CLASSIFICATION REGRESSION OF ANNOYANCE G ON SOCIAL AND ACOUSTICAL VARIABLES

PREDICTORS	BETA VALUES																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Noise Susceptibility	0.145	0.154	0.147	0.152	0.149	0.152	0.154	0.307	0.470	0.307	0.149	0.152	0.156	0.156	0.152	0.155	0.153
Fear	0.369	0.324	0.331	0.325	0.330	0.334	0.328	0.428	0.557	0.429	0.337	0.321	0.324	0.329	0.326	0.325	0.327
Adaptability	0.210	0.185	0.194	0.190	0.194	0.194	0.187	0.196	0.191	0.193	0.195	0.188	0.183	0.185	0.188	0.187	0.192
Misfeasance	0.149	0.135	0.142	0.133	0.143	0.141	0.135	0.138	0.147	0.136	0.141	0.133	0.135	0.135	0.142	0.134	0.136
Importance	0.123	0.102	0.102	0.103	0.101	0.102	0.106	0.105	0.107	0.106	0.108	0.101	0.104	0.108	0.101	0.104	0.104
Distance	0.073	0.062	0.053	0.061	0.061	0.059	0.053	0.065	0.057	0.057	0.046	0.052	0.058	0.044	0.061	0.055	0.061
CNR	-	0.232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_{NP}(Day)	-	-	0.205	-	-	-	-	-	-	-	-	0.111	-	-	-	-	-
L_{NP}(Night)	-	-	-	0.228	-	-	-	-	-	-	-	0.278	-	-	-	-	-
L_{NP}(Total)	-	-	-	-	0.200	-	-	-	-	-	-	-	-	-	-	-	-
L_{EQ}(Day)	-	-	-	-	-	0.198	-	-	-	-	-	-	0.115	0.144	0.130	-	-
L_{EQ}(Night)	-	-	-	-	-	-	0.226	-	-	-	-	-	0.209	0.309	-	0.198	-
L_{EQ}(Total)	-	-	-	-	-	-	-	0.202	-	-	-	-	-	-	-	-	0.151
ST DEV (Day)	-	-	-	-	-	-	-	-	0.201	-	-	-	0.087	-	0.131	-	-
ST DEV (Night)	-	-	-	-	-	-	-	-	-	0.179	-	-	0.071	-	-	0.076	-
ST DEV (Total	-	-	-	-	-	-	-	-	-	-	0.184	-	-	-	-	-	0.118
Multiple R	0.682	0.707	0.703	0.707	0.701	0.701	0.707	0.701	0.702	0.701	0.700	0.711	0.710	0.709	0.706	0.708	0.705
Multiple R^2	0.465	0.500	0.494	0.501	0.492	0.491	0.500	0.491	0.493	0.491	0.489	0.505	0.504	0.502	0.498	0.501	0.497
R^2 Rank	17	6.5	10	4.5	11	14	6.5	14	12	14	16	1	2	3	8	4.5	9

4.3.4 Summary of Prediction Models - Table 8 summarizes the Multiple R^2 rankings of Tables 3-7. The entries in this table have been ordered by mean rank, but caution should be used in assigning significance to this ordering. The prediction accuracy of any acoustical variable or combination of variables differs very little from any other acoustical variable. With this reservation, it can be seen that the two variables L_{NP}(Day) and L_{NP}(Night) correlate with annoyance about as well as CNR in each of the three prediction models. The variable L_{NP}(Total) was a poorer predictor, while the four variable set $\{L_{EQ}$(Day), ST DEV (Day), L_{EQ}(Night), ST DEV (Night)$\}$, followed closely by $\{L_{EQ}$(Day), L_{EQ}(Night)$\}$ and by L_{EQ}(Night) are generally the best acoustical predictors.

TABLE 8

MULTIPLE R^2 RANKING OF ACOUSTICAL MEASURES

COLUMN REFERENCE		ACOUSTICAL PREDICTOR VARIABLES INCLUDED	LINEAR REGRESSION MODEL		CLASSIFICATION REGRESSION MODEL (ACOUSTICAL AND SOCIAL VARIABLES)
Tables 3-4	Tables 5-7		ACOUSTICAL VARIABLES ONLY	ACOUSTICAL AND SOCIAL VARIABLES	
12	13	L_{EQ}(Day), L_{EQ}(Night) ST DEV (Day), ST DEV (Night)	1	1	2
13	14	L_{EQ}(Day), L_{EQ}(Night)	2	2	3
15	16	L_{EQ}(Night), ST DEV (Night)	3	3	4.5
11	12	L_{NP}(Day), L_{NP}(Night)	6	6	1
1	2	CNR	4	4.5	6.5
6	7	L_{EQ}(Night)	5	4.5	6.5
3	4	L_{NP}(Night)	8.5	7	4.5
16	17	L_{EQ}(Total), ST DEV (Total)	7	8.5	9
14	15	L_{EQ}(Day), ST DEV (Day)	10.5	10.5	8
7	8	L_{EQ}(Total)	8.5	8.5	14
4	5	L_{NP}(Total)	12	12	11
5	6	L_{EQ}(Day)	10.5	10.5	14
2	3	L_{NP}(Day)	13	13	10
8	9	ST DEV (Day)	15	15	12
9	10	ST DEV (Night)	14	14	14
10	11	ST DEV (Total)	16	16	16
-	1	None	-	17	17

4.3.5 Optimum Coefficients - Robinson's original definition of L_{NP} is

$$L_{NP} = L_{EQ} + k\sigma$$

where k is to be determined. He then proposes the value k = 2.56 as reasonable in view of his analyses. He also proposes to consider day and night exposures separately.

Examination of the raw score weights in Tables 4 and 6 reveals that, for the data used, linear regression generally yields:

(1) the ratio of the weight of σ to the weight of L_{EQ} is negative, with values near -1.0, when these variables appear together.

(2) the ratio of the weights of L_{EQ}(Night) and L_{EQ}(Day) is also negative, with values near -1.4, when these variables appear together.

Thus it appears that for these data the following equation provides a more accurate annoyance predictor than the existing L_{NP} formulation:

$$L_X = -1.0 \left[L_{EQ}(\text{Day}) - \sigma(\text{Day})\right] + 1.4 \left[L_{EQ}(\text{Night}) - \sigma(\text{Night})\right]$$

When tested in the regression models, this measure did in fact perform better than any of the other acoustical predictor variables or sets of variables. This rather peculiar result seems to have originated from the following properties of the data base:

(1) L_{EQ}(Day) and L_{EQ}(Night) are very highly correlated.

(2) There is a limited range of exposure represented in the data.

(3) L_{EQ} and σ are functionally related (but not linearly) under the assumptions described in Appendix A.

It is necessary to conclude that the data base used does not contain sufficient data to validate the σ-coefficient of 2.56 or to establish a proper day-night weighting. In all probability these constants must be determined in studies covering a wider range of exposures and sources, and in which L_{EQ} and σ are available directly from the acoustical data.

4.3.6 Comparison with Other Noise Measures - Multiple classification analyses were performed on data from four survey cities for CNR, NEF, NNI', and several other acoustical exposure measures used as predictors of annoyance (TRACOR, 1970). These measures were calculated for each respondent in each of the first four cities. Noise Exposure Forecast values were calculated from one-second sampling of one-third octave band spectra, with discrete frequency and duration corrections (Bishop, 1967). The Noise and Number Index (Wilson, 1963) was calculated from the energy average of the maximum flyover PNL values (APNL) by:

$$NNI = APNL + 15 \log N - 80$$

where N is the total number of aircraft flyovers. To combine day and night values of NNI, a time correction of 17 NNI units was introduced for night exposure to form:

$$NNI' = 10 \log(\text{antilog} \frac{NNI_D}{10} + \text{antilog} \frac{NNI_N + 17}{10})$$

As explained in the TRACOR report, the above analyses were performed with a slightly different annoyance metric, Annoyance V. In these analyses, an extra social predictor ("City") provided increased predictive power.

Table 9 shows the results of multiple classification analyses performed in the earlier study. It can be seen from the beta values that CNR was a slightly "better" acoustical exposure measure for these data than was NEF or NNI'. The additional social variable "City" was a predictor variable for Annoyance V, but is not for Annoyance G. This extra variable and the somewhat different definitions of Annoyance makes direct comparison of Tables 7 and 9 impossible. These two tables can be related, however, through the variable CNR included in the

TABLE 9

MULTIPLE CLASSIFICATION OF ANNOYANCE V ON PREDICTOR VARIABLES (AFTER TRACOR, 1970)

PREDICTORS	BETA VALUES			
	1	2	3	4
Noise Susceptibility	0.27	0.27	0.27	0.28
Fear	0.38	0.36	0.37	0.37
Adaptability	0.18	0.17	0.18	0.18
Misfeasance	0.07	0.06	0.06	0.06
Importance	0.05	0.05	0.05	0.05
Distance	0.25	0.19	0.20	0.24
City	0.15	0.12	0.13	0.13
CNR	-	0.16	-	-
NNI'	-	-	0.13	-
NEF	-	-	-	0.12
Multiple R	0.78	0.79	0.79	0.79
Multiple R^2	0.61	0.63	0.62	0.62

present analyses. While neither the beta values nor the Multiple R values are directly comparable, there is no reason to believe that the ordering of predictors would change significantly, in view of the relatively high correlations between the noise exposure variables and the relatively moderate contribution of such variables to the prediction of annoyance in this model. Since the variable set $\{L_{NP}(\text{Day}), L_{NP}(\text{Night})\}$ is as good as, or better than, the variable CNR, and CNR was slightly better than NEF or NNI', the L_{NP} set should be superior to either NEF or NNI' for the data base used in this study.

4.4 Prediction of Central Tendency

Either CNR or L_{NP} appears to be an adequate predictor of mean and/or median annoyance in a group of individuals. Figure 1 shows the mean and median annoyance of respondents by CNR classes. (Classes with fewer than 30 respondents, or 1% of the sample, have been deleted.) The least squares regression lines through these points are also shown. Figures 2, 3, and 4 are the corresponding graphs for Annoyance G versus L_{NP}(Day), L_{NP}(Night), and L_{NP}(Total), respectively. Table 10 gives the regression formulae, the correlation coefficients between the sample points and the regression lines, and the standard error of the estimate. To the extent that the samples in the class intervals of the acoustical variables represent the responses of the population living in that exposure class, it is possible to estimate mean or median annoyance in an area quite accurately with any of these four measures.

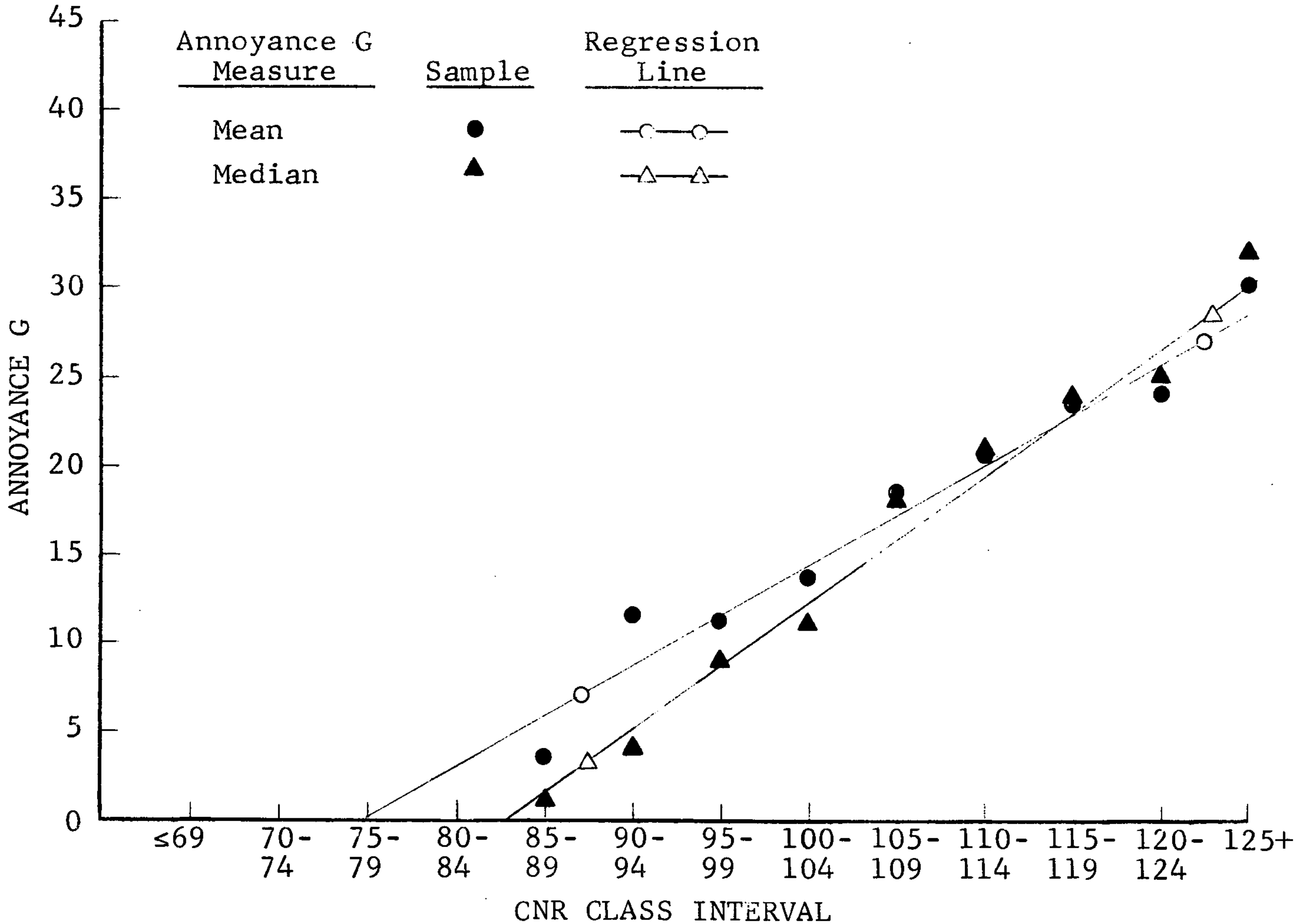

FIGURE 1 - MEAN AND MEDIAN ANNOYANCE G VERSUS CNR

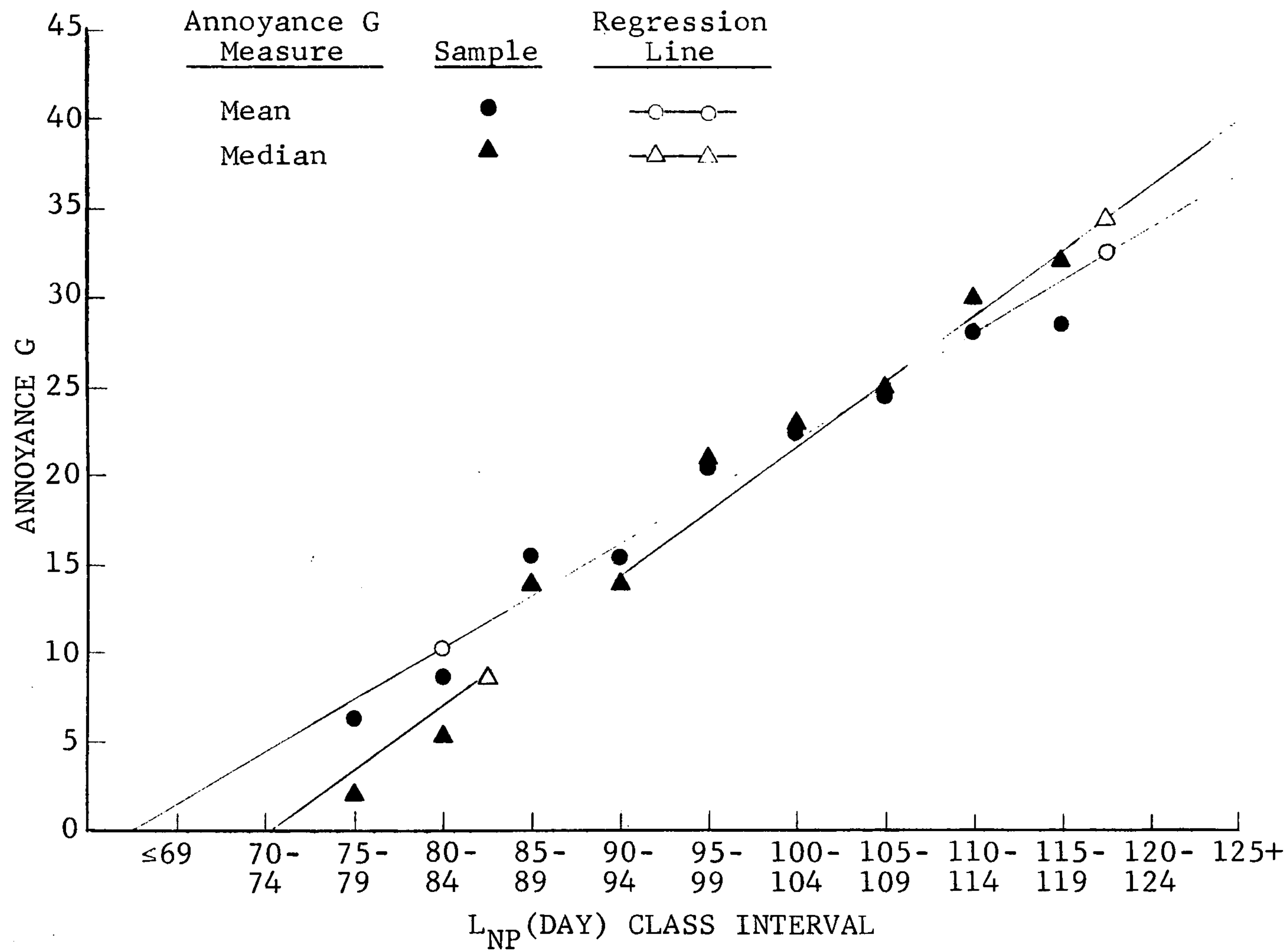

FIGURE 2 - MEAN AND MEDIAN ANNOYANCE G VERSUS L_{NP}(DAY)

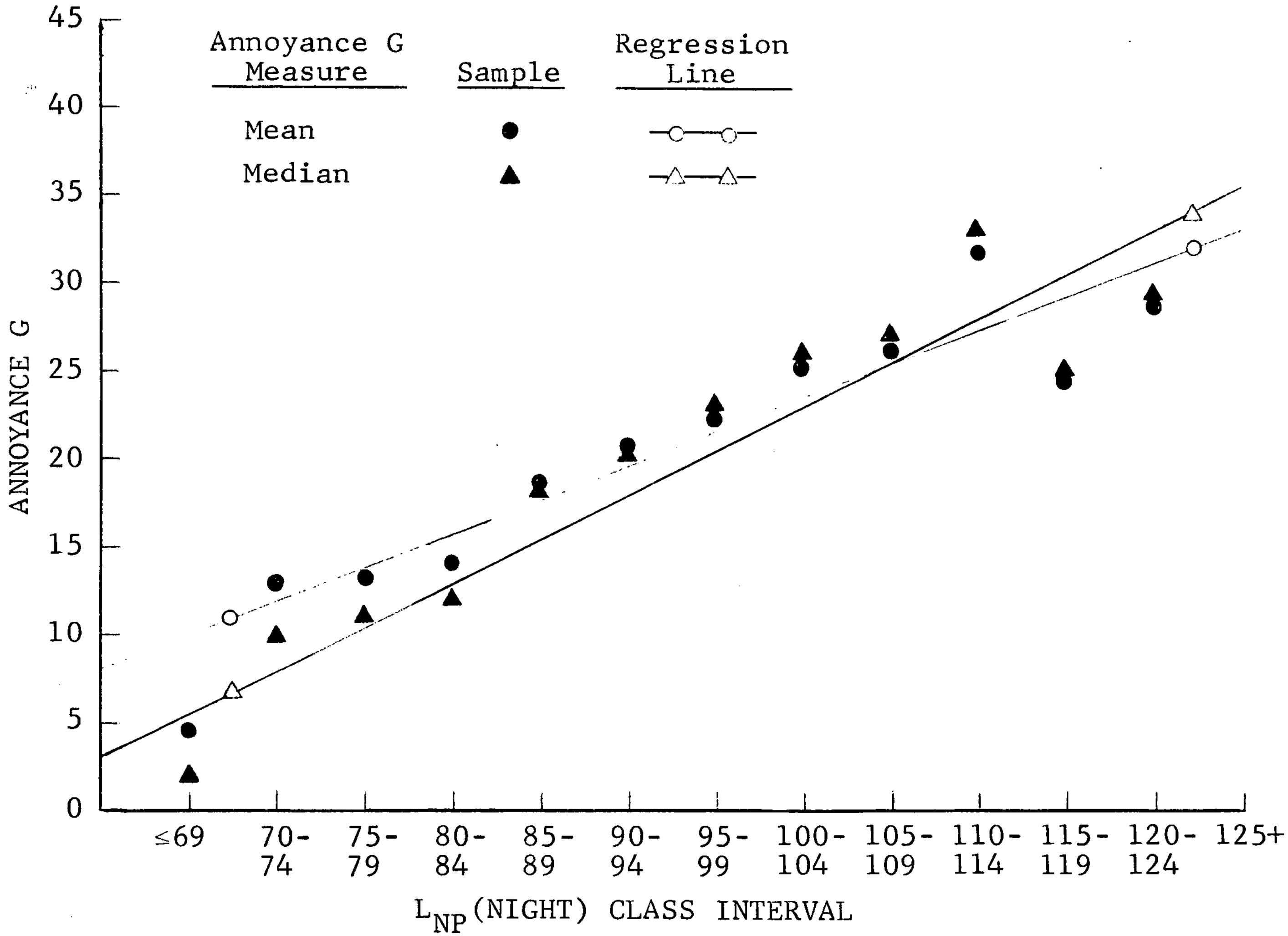

FIGURE 3 - MEAN AND MEDIAN ANNOYANCE G VERSUS L_{NP}(NIGHT)

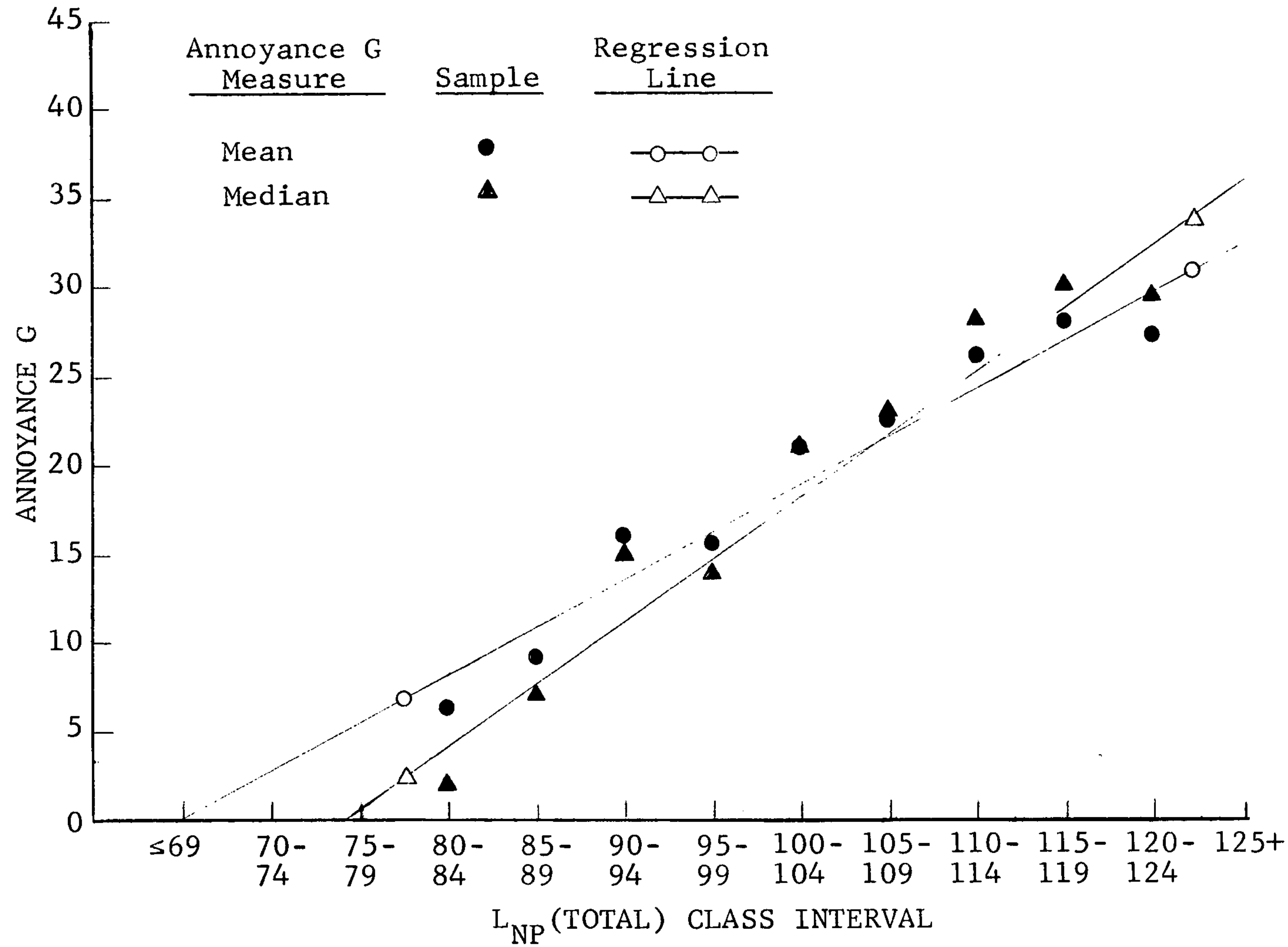

FIGURE 4 - MEAN AND MEDIAN ANNOYANCE G VERSUS L_{NP}(TOTAL)

TABLE 10

PREDICTION OF MEAN AND MEDIAN ANNOYANCE G BY CNR AND L_{NP}

Acoustical Measure (X)	Number of 5 dB Class Intervals	Prediction of Mean Annoyance ($\bar{A}$)				Prediction of Median Annoyance (A_{50})			
		$\bar{A} = a + bX$		Correlation (r)	Std. Error ($S_y \cdot x$)	$A_{50} = c + dX$		Correlation (r)	Std. Error ($S_y \cdot x$)
		a	b			c	d		
CNR	9	-44.8	0.580	0.981	1.66	-64.0	0.747	0.992	1.38
L_{NP}(Day)	9	-37.2	0.577	0.983	1.57	-54.5	0.748	0.985	1.89
L_{NP}(Night)	12	-18.2	0.407	0.939	2.82	-26.4	0.485	0.941	3.31
L_{NP}(Total)	9	-37.4	0.554	0.972	1.95	-54.3	0.713	0.973	2.47

5.0 SALIENT RESULTS

The following results are based upon the analysis of response to aircraft noise described in the previous sections. There is no intention to imply that these results might obtain for other noise sources or for other measures of response than Annoyance G.

(1) It is easier to compute CNR, NEF, or NNI for communities surrounding an airport than to compute L_{NP} or TNI, using aircraft-related data.

(2) It is easier to directly measure L_{NP} than to measure CNR, NEF, or NNI; it is also easier to measure L_{EQ} than L_{NP}.

(3) Whether used alone or with social variables, the four best single acoustical predictors of annoyance in linear regression models are: CNR, L_{EQ}(Night), L_{NP}(Night), and L_{EQ}(Total) (in descending order).

(4) Whether used alone or with social variables in linear models, or with social variables in a nonlinear model, the following combinations of acoustical variables were better predictors of annoyance than CNR (in descending order):

$\{L_{EQ}(\text{Day}),\ \sigma(\text{Day}),\ L_{EQ}(\text{Night}),\ \sigma(\text{Night})\}$

$\{L_{EQ}(\text{Day}),\ L_{EQ}(\text{Night})\}$

$\{L_{EQ}(\text{Night}),\ \sigma(\text{Night})\}$

(5) Use of acoustical and social variables in a nonlinear model slightly improved the relative performance of L_{NP}, so that $\{L_{NP}(Day), L_{NP}(Night)\}$ and $L_{NP}(Night)$ are also superior to CNR as annoyance predictors.

(6) Results (3), (4), and (5) above are all of statistical significance because of the large sample size, but for practical purposes all of the measures mentioned are of equivalent predictive ability.

(7) CNR and $L_{NP}(Any)$ are equally good predictors of mean and median annoyance of a sample population.

6.0 CONCLUSIONS

(1) There is no practical difference between CNR, L_{NP}(Night), and L_{EQ}(Night) in the prediction of individual or average annoyance from aircraft noise.

(2) For calculation or estimation of aircraft noise exposure CNR is the most practical measure.

(3) For measurement of noise exposure using automated equipment L_{NP} or L_{EQ} are the most practical measures, presuming it is possible to determine L_{NP}(Night) or L_{EQ}(Night).

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APPENDIX A

Calculation of L_{NP}

A1.0 CALCULATION OF L_{NP}

In order to calculate L_{NP} for communities which experience a significant number of aircraft overflights the following assumptions are made in this report:

(1) The time signature of the aircraft overflight is triangular in shape with a maximum Perceived Noise Level of P, has a duration within 10 PNdB of P of d seconds, and terminates at the median ambient level of A PNdB after a total of T seconds.

(2) Each aircraft type, operation type, and flight path may produce differing values of P and d at a given location.

(3) The ambient level A is the median background level. The distribution of background levels is assumed to be Gaussian with standard deviation σ_A.

A schematic representation of these assumptions is shown in Figure A.1 for two aircraft overflights.

The proposed formulation for L_{NP} is

$$L_{NP} = L_{EQ} + k\sigma$$

where L_{EQ} = energy mean level

σ = standard deviation of levels

k = a constant (provisionally $k = 2.56$)

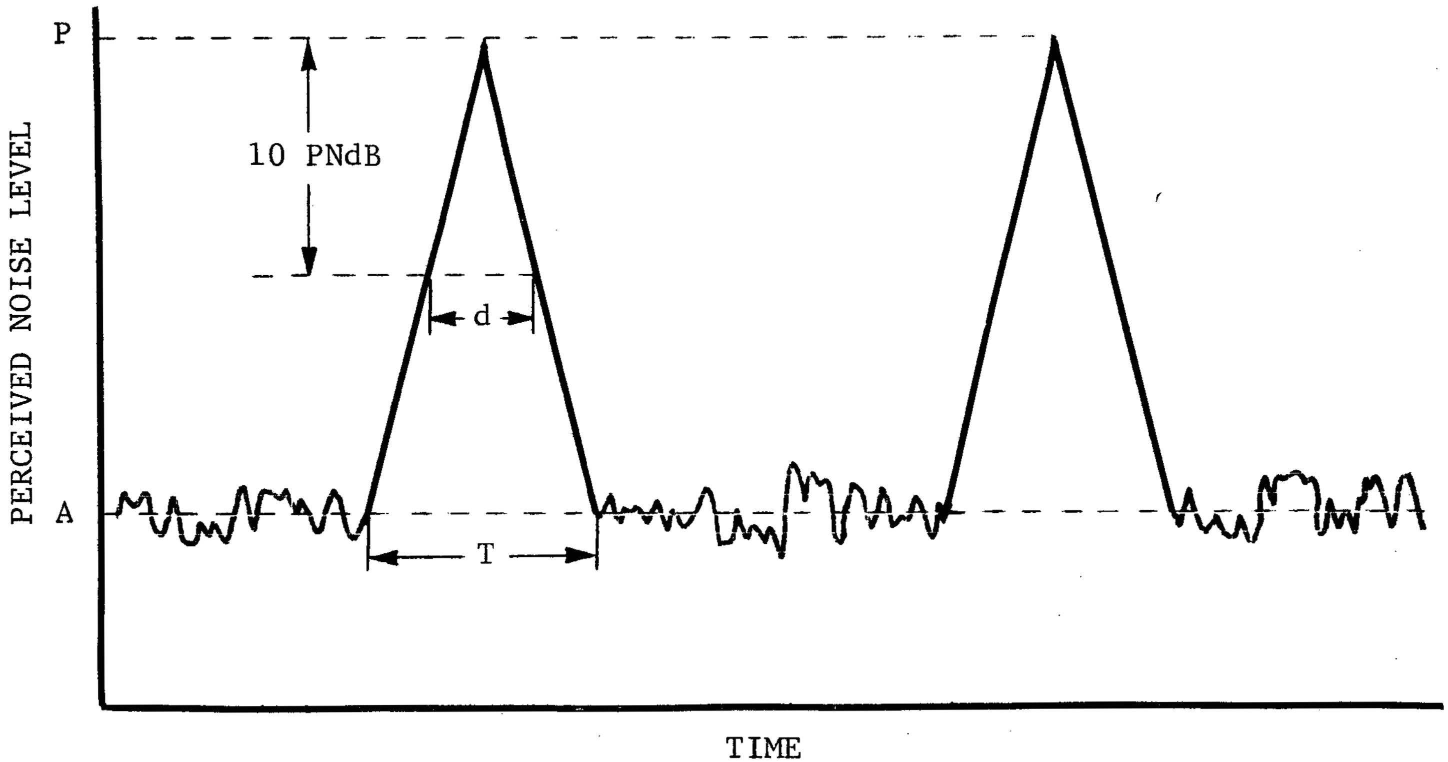


FIGURE A.1 - SCHEMATIC REPRESENTATION OF TIME HISTORY OF GAUSSIAN-DISTRIBUTED BACKGROUND NOISE AND TWO AIRCRAFT OVERFLIGHTS

In calculation of L_{NP}, the provisional value k = 2.56 has been used throughout. All levels used for this study are expressed in PNdB, or dB(PN) in Robinson's notation.

The procedure used for calculation of L_{NP} is as follows:

(1) Separate the measurement period into the period during which flyovers occur and the period during which the background prevails.

(2) Calculate L_{EQ} and total duration for each period.

(3) Calculate the components of σ for each period.

(4) Combine the periods to obtain a composite L_{EQ} and a composite σ from which L_{NP} is directly obtained.

For discrete sample data the definitions of L_{EQ} and σ are:

$$L_{EQ} = 10 \log_{10} \left[\frac{\sum_{i=1}^{N} 10^{(x_i/10)}}{N} \right]$$

$$\sigma = \left[\frac{\sum_{i=1}^{N} x_i^2}{N} - \left(\frac{\sum_{i=1}^{N} x_i}{N} \right)^2 \right]^{\frac{1}{2}}$$

where x_i = ith level sample in PNdB

N = total number of samples

If the x_i levels above are samples of a known function of time, x(t), these quantities can be solved analytically using the continuous function equivalent equations:

$$L_{EQ} = 10 \log_{10} \left[\int_{t=t_0}^{t_1} 10^{(x/10)} \, dt / (t_1 - t_0) \right]$$

$$\sigma = \left\{ \int_{t=t_0}^{t_1} x^2 \, dt/(t_1 - t_0) - \left[\int_{t=t_0}^{t_1} x \, dt/(t_1 - t_0) \right]^2 \right\}^{\frac{1}{2}}$$

In practice, for computational convenience three quantities are accumulated for the period of interest:

$$E = \int 10^{x/10} \, dt \quad \text{(total energy)}$$

$$I = \int x \, dt \quad \text{(sum of x)}$$

$$J = \int x^2 \, dt \quad \text{(sum of } x^2\text{)}$$

A1.1 Aircraft Flyovers

For the triangular signatures of Figure A.1, x is a known function of t. The quantities of interest for a single flyover with max PNL of P, duration d, total time T, and ambient A are:

$$E_1 = 2 \int_{t=t_0}^{t_0+T/2} 10^{x(t)/10} \, dt$$

$$= 0.434\ d(10^{A/10})(10^{T/d} - 1)$$

An equivalent and sometimes more convenient form is

$$E_1 = 0.434\ d(10^{A/10})\ (10^{\Delta/10} - 1)$$

where $\Delta = P - A$, the difference in maximum PNL and ambient levels.

$$I_1 = 2 \int_{t=t_0}^{t_0+T/2} x(t)\ dt$$

$$= \frac{\Delta d}{20} [\Delta + 2A]$$

$$J_1 = 2 \int_{t=t_0}^{t_0+T/2} (x(t))^2\ dt$$

$$= \frac{\Delta d}{10} \left[\frac{\Delta^2}{3} + A\Delta + A^2\right]$$

Equivalent forms for E_1, I_1, and J_1 using the maximum PNL P and ambient level A are

$$E_1 = 0.434\ d(10^{P/10} - 10^{A/10})$$

$$I_1 = \frac{d}{20} (P^2 - A^2)$$

$$J_1 = \frac{d}{30} (P^3 - A^3)$$

When there are multiple flyovers with the same maximum PNL, duration, and ambient, each of these quantities is multiplied by the number of aircraft movements (which may in practice be non-integer for average numbers of movements.) Differing peak levels, durations, or ambients require a separate calculation of E_1, I_1, and J_1, and these quantities are classes of overflight:

$$E_1 = \sum_{j=1}^{m} E_{1j} n_j$$

$$I_1 = \sum_{j=1}^{m} I_{1j} n_j$$

$$J_1 = \sum_{j=1}^{m} J_{1j} n_j$$

$$T_1 = \sum_{j=1}^{m} T_{1j} n_j$$

where m = number of distinct classes of operation,

n_j = number of aircraft overflights in class j, and

T_1 = total elapsed time of overflight (in seconds)

A1.2 Background Levels

In the absence of aircraft overflight it is assumed that there exists a distribution of background levels with median A and standard deviation σ_A. This distribution is assumed to be Gaussian. For this case it is not possible to define x as a known function of time, but from the properties of Gaussian distributions it is possible to determine E_2, I_2, and J_2:

$$E_2 = T_2 \int_{-\infty}^{+\infty} p(x)\ 10^{x/10}\ dx$$

$$= T_2 \int_{-\infty}^{+\infty} f(z)\ 10^{(\sigma_A z + \bar{x})/10}\ dz$$

where T_2 = total duration of background levels

$p(x)$ = probability of occurrence of level x

$\bar{x}$ = A, the median background level

z = $(x - \bar{x})/\sigma_A$, the standard score for x

$f(z)$ = $e^{-z^2/2}/\sqrt{2\pi}$, the Gaussian distribution function

Solution of this integral in terms of T_2, A, and σ_A yields

$$E_2 = T_2 \cdot 10^{(A + \sigma_A{}^2/8.686)}$$

Similarly,

$$I_2 = T_2 \int_{-\infty}^{+\infty} z\ f(z)\ dz$$

$$= T_2 \cdot A$$

$$J_2 = T_2 \int_{-\infty}^{+\infty} z^2\ f(z)\ dz$$

$$= T_2 \cdot (A^2 + \sigma_A{}^2)$$

A1.3 Computation of L_{NP}

If E_1, I_1, J_1, E_2, I_2, and J_2 are defined as above, let

$$E_0 = E_1 + E_2$$

$$I_0 = I_1 + I_2$$

$$J_0 = J_1 + J_2$$

$$T_0 = T_1 + T_2$$

The mean values of energy, level, and level squared are then:

$$\overline{E} = E_0/T_0$$

$$\overline{I} = I_0/T_0$$

$$\overline{J} = J_0/T_0$$

Using these definitions L_{NP} is computed as follows:

$$L_{EQ} = 10 \log_{10}\overline{E}$$

$$\sigma = (\overline{J} - \overline{I}^2)^{\frac{1}{2}}$$

$$L_{NP} = L_{EQ} + 2.56\sigma$$

$$= 10 \log_{10} \overline{E} + 2.56(\overline{J} - \overline{I}^2)^{\frac{1}{2}}$$

A2.0 COMPUTATION OF L_{NP} FOR BASE DATA

Examination of the equations in the previous section indicates that for the assumptions made (triangular aircraft signature rising out of the median ambient followed by background levels with a Gaussian distribution) the following four quantities must be determined:

(1) Max PNL of each flyover, and number of flyovers

(2) Duration of each flyover

(3) Median background level

(4) Standard deviation of background levels

Of these four quantities only the first is necessary for the calculation of CNR. L_{NP} was calculated for day operations (7:00 a.m. to 10:00 p.m. local time), for night operations (10:00 p.m. to 7:00 a.m.), and for the 24-hour day for each of the 2912 survey respondents. In practice this was accomplished by calculating L_{NP} values for each of the 177 census tracts surveyed. Normally, census tracts were geographically large enough that they were further subdivided into several sample blocks for more accurate estimation of the maximum PNL of each aircraft category.

A2.1 Acoustical Survey Data

For each sample block the peak PNL of arrivals and of departures for several aircraft types was available. These levels were obtained by combining available PNL contours with field measurements. Approximately 30% of the census tracts surveyed were monitored for noise exposure, with approximately 100 aircraft signatures per sample. As described by Connor (1968), these data were analyzed in one second third octave band spectra together with dBA and dBN levels. These spectra were then used to compute the following measures for each overflight:

Max dB(A) and duration dB(A)

Max dB(N) and duration dB(N)

Max PNdB and duration PNdB (1/3 octave band)

Max $PNdB_t$ and duration $PNdB_t$ (PNdB with discrete frequency correction)

Max Phons (Stevens Mark VI)

Max SIL's (three varieties of Speech Interference Level)

Peak PNdB (from nonsimultaneous 1/3 octave band peaks)

In addition to above measures the instantaneous (one second) values of each were recorded.

A2.2 Estimation of the Maximum PNL Values

In the previous TRACOR study based on the data used here, CNR values were computed for every sample block of the social survey. As a result of that computation the Peak PNL values for each type of aircraft and each flight path were available in computer-readable form, as were the average number of daytime and nighttime operations for each flight path. These Peak PNL data were used to estimate maximum PNL values by subtraction of 1.4 PNdB. (This correction figure is the mean difference between these two measures found in the analysis of 4730 flyovers in the earlier study (Connor, 1968).)

A2.3 Estimation of Flyover Durations

For computation of L_{NP} it was necessary to estimate the duration of each flyover. Durations were available for the acoustical survey areas. For these areas separate durations were measured for arrivals and for departures. Where possible, values for nearby census tracts were interpolated from available measurements. For census tracts which were too far removed from actual samples for interpolation, a regression analysis was performed. From this analysis durations were estimated by the following equations:

$$d_a = 90.7 - 0.758\ P \qquad r = -0.81$$

$$d_d = 72.4 - 0.535\ P \qquad r = -0.63$$

where d_a = arrival duration

d_d = departure duration

P = max PNL of the flyover

r = correlation coefficient between duration and max PNdB.

For the regression data these equations predict the arrival durations with a standard error of 3.8 seconds. For departures the standard error is 4.2 seconds. These equations compare favorably with similar equations developed by Serendipity (1970, Vol. VI).

A2.4 Median Background Levels

Estimation of the median daytime background level A was performed by reference to the original field logs used in the acoustical surveys. A-weighted ambient sound levels as well as some octave band levels were recorded by the field crews. Their instructions were to estimate the median background level in the absence of aircraft after observing the sound analyzer reading for approximately 20 seconds. These levels were recorded approximately once every 25 overflights. While there was no intent to use these data in the original sample design, it is believed that the mean of these ambient levels is a reasonable estimate of the median daytime background level. The range of levels observed was 37 dBA to 63 dBA, corresponding fairly well to the range of L_{50} levels observed in other residential areas (Serendipity, Vol. VI, 1970; Serendipity, 1971). Areas which were not included in the acoustical survey were assigned the median background level of the nearest similar survey area.

Very few ambient level data were taken during the nighttime period. For this reason the median nighttime background level was estimated from the corresponding daytime level. Serendipity data (Vol. VI, 1970) indicated that night residential medians differed from day medians by 10 dBA to 18 dBA, depending upon traffic density at various hours. For the purpose of computation of L_{NP}(Night) it was assumed that the median background level between 10:00 p.m. and 7:00 a.m. was 12 dBA lower than the daytime median.

For consistency with the flyover levels, a constant of 12.6 was added to the median background dBA levels to approximate median Perceived Noise Levels (Kryter, 1968).

A2.5 Standard Deviation of Background Levels

The standard deviation of background levels was assumed to be 10% of the median background level in PNdB. For more accurate estimation the following equations from the Medford Study (Serendipity, 1971) could be used:

$$L_{90} = -1.10 + 0.95\ L_{50}$$

$$L_{10} = 27.63 + 0.64\ L_{50}, \text{ or}$$

$$L_{10} - L_{90} = 28.73 - 0.31\ L_{50}$$

The assumption of Gaussian distribution implies that

$$L_{10} - L_{90} = 2.56\sigma_A, \text{ or}$$

$$\sigma_A = 11.21 - 0.1211\ L_{50}$$

where L_{10} = dBA level exceeded 10% of the time

L_{90} = dBA level exceeded 90% of the time

L_{50} = dBA level exceeded 50% of the time

σ_A = standard deviation of background level

Section A3.3 shows that L_{NP} is highly dependent upon σ_A for small numbers of aircraft overflights, but that the approximation used is reasonably accurate.

A3.0 COMPARISON WITH ORIGINAL NOISE POLLUTION LEVEL DOCUMENT

In his original report setting forth the L_{NP} concept (1969), Robinson presented some example computations. His assumptions were not identical to those in Section A1.0 of this report, but were quite similar. In particular, he used a slightly more complex aircraft flyover noise signature and assumed a non-fluctuating background level ($\sigma_A = 0$). Figure A.2 shows Robinson's assumed signature compared with triangular signatures, used in this report, of 24 and 32 seconds duration.

Robinson used three example situations for his calculations. Figure A.3 (reproduced from his paper) illustrates his Cases A, B, and C in terms of the distribution of flyover peak levels. For each case he also considered the effect of background levels ranging from 70 to 85 PNdB (dB(PN) in Robinson's notation).

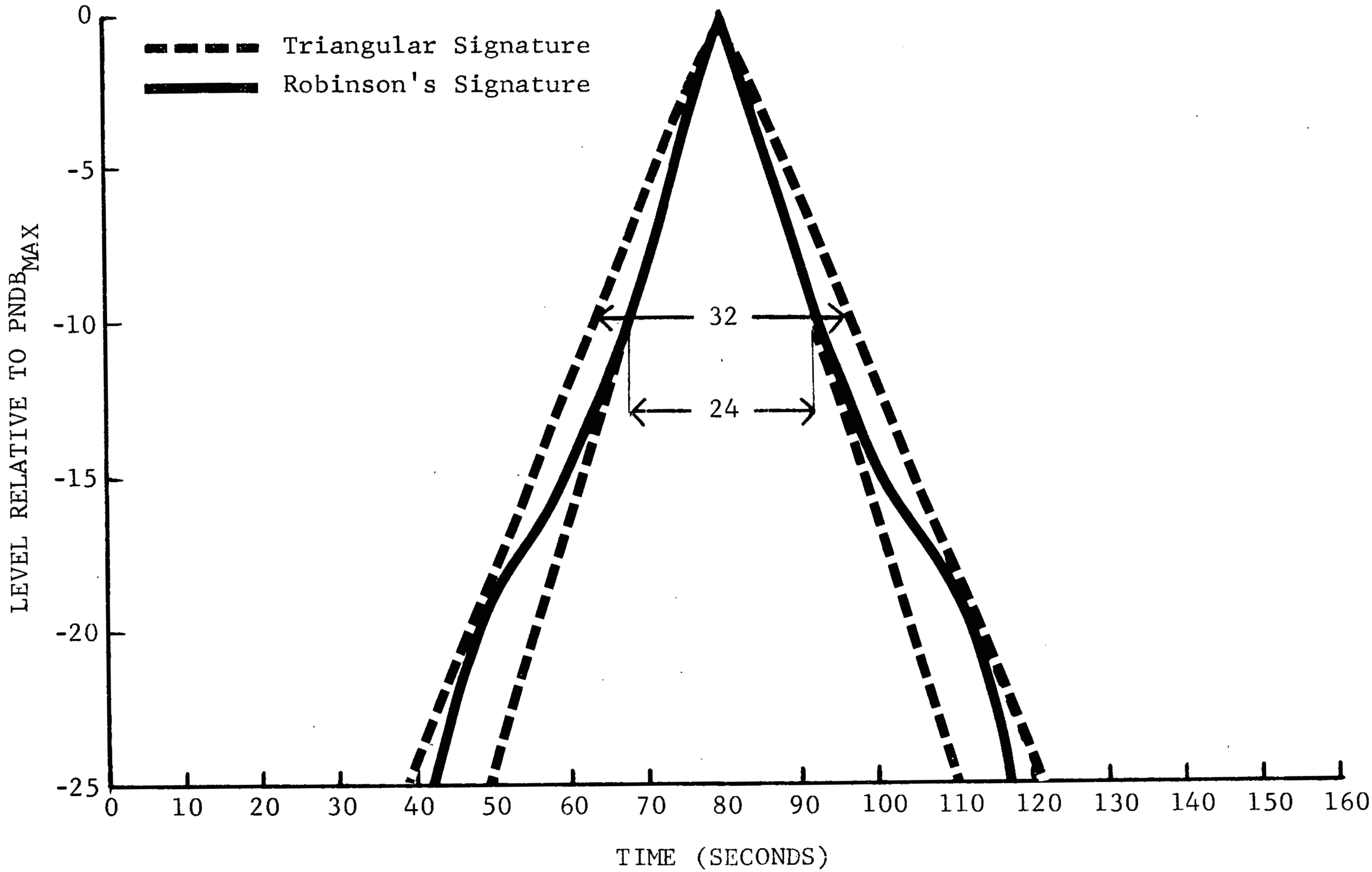


FIGURE A.2 - COMPARISON OF ASSUMED AIRCRAFT FLYOVER NOISE SIGNATURES

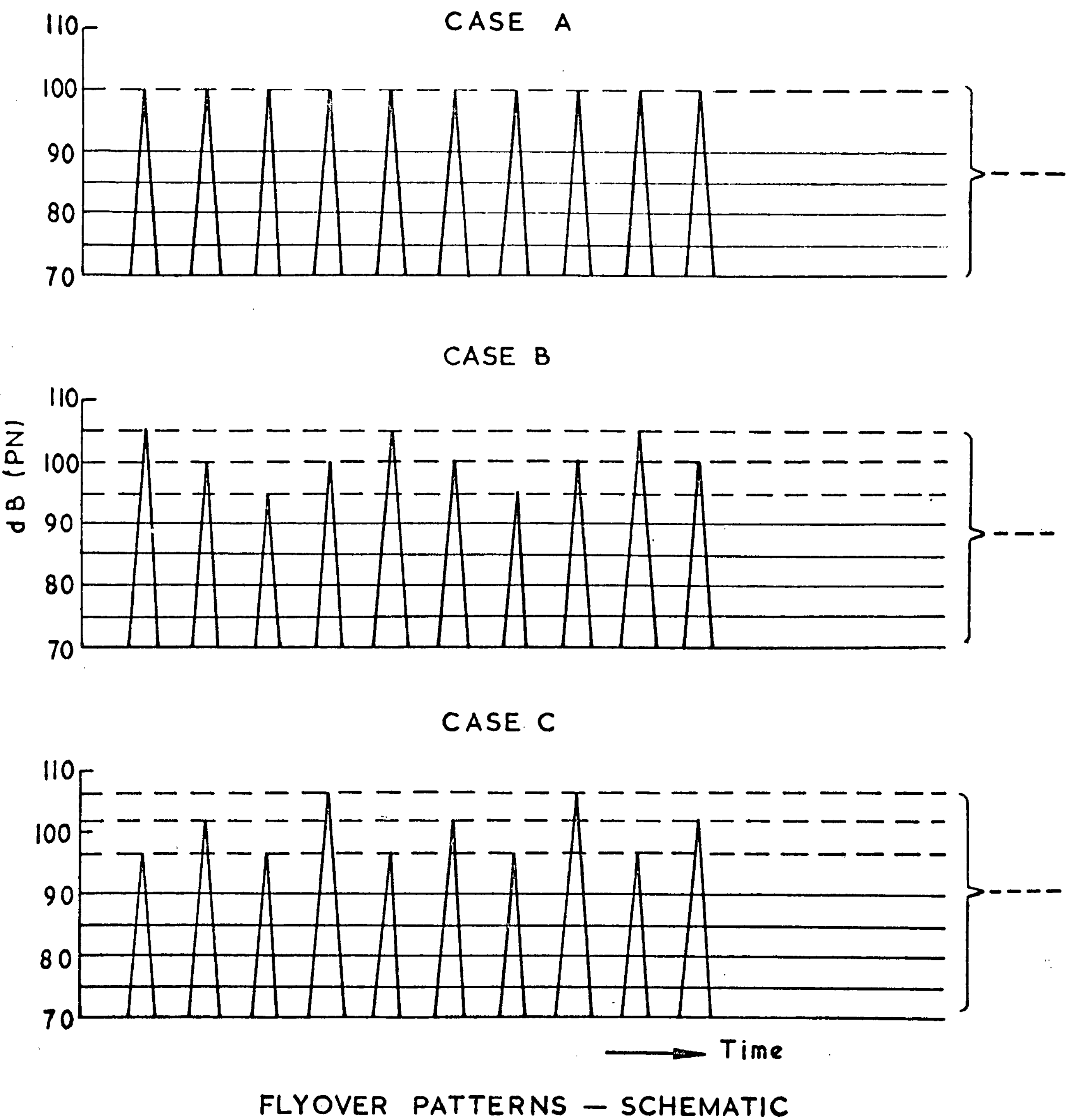


FIGURE A.3 - ROBINSON'S TEST CASES (FROM ROBINSON, 1969)

A3.1 Effect of Differing Signatures

Figure A.4 compares Robinson's Case A results for a given number of overflights with results computed as in Section A1.0 for 24-second and 32-second durations. In each case the curve is the average for background levels of 70, 75, 80, and 85 PNdB, with the given number of overflights having maximum levels of 100 PNdB. L_{NP} is calculated for an assumed 15-hour period. The curve representing Robinson's results is taken from Figure 5 of his report. The three curves are quite close until the number of overflights becomes large. The small differences seen for large numbers of operations can be explained by the differences in signatures.

Figure A.5 compares Case A and Case C averages (over differing backgrounds) for 24-second triangular signatures and Robinson's signatures. There is again some difference in the curves for large numbers of operations. There are also differences for small numbers of operations which cannot be explained by the shape of the aircraft signature. These latter differences are most likely due to computational error. As the number of overflights approaches zero, it is clear that Case A and Case C must approach the same L_{NP} values, so that the TRACOR curves seem more plausible than the others.

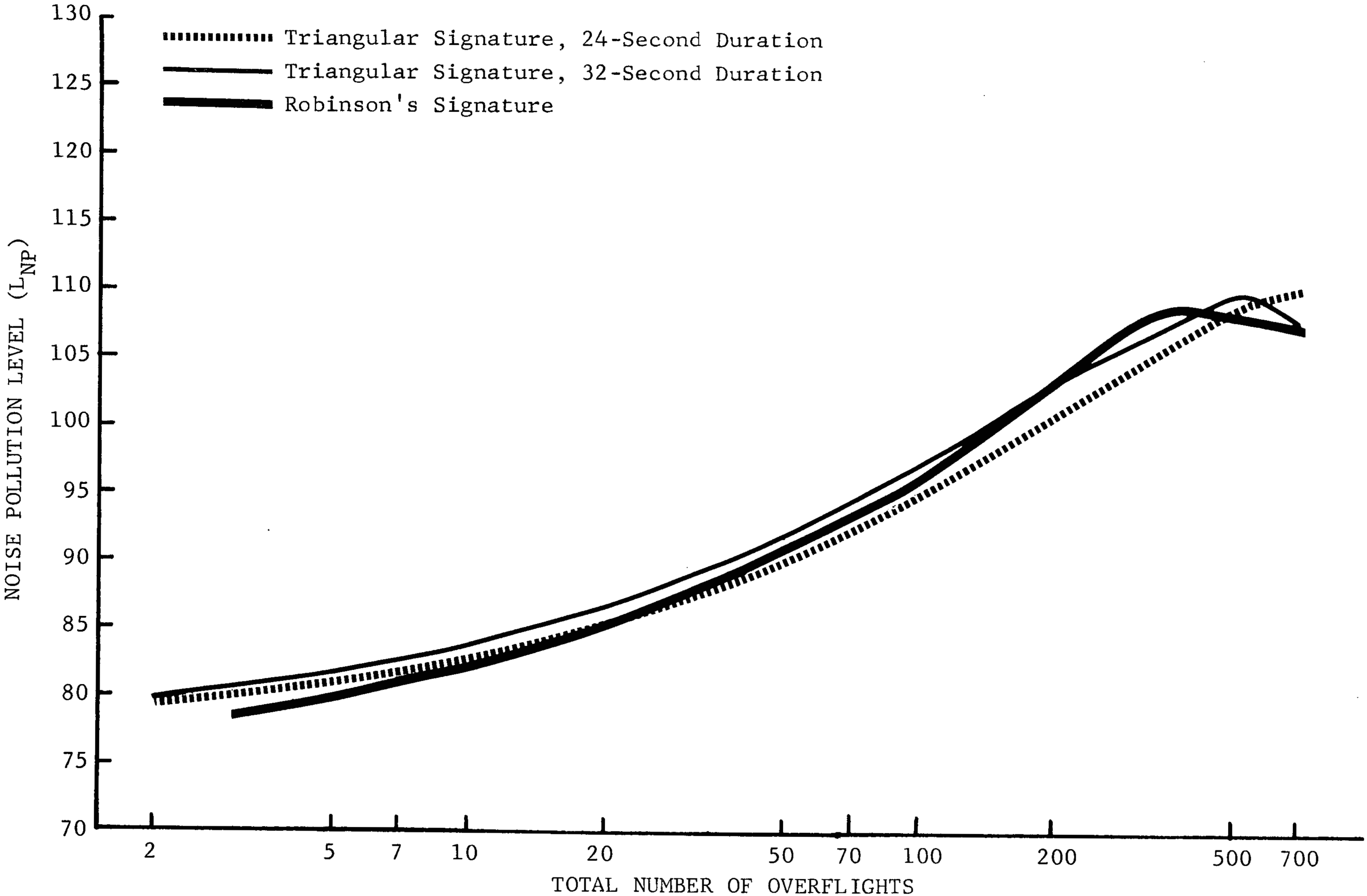


FIGURE A.4 - EFFECT OF AIRCRAFT SIGNATURE ON L_{NP}
(Case A; 70-85 PNdB Ambients)

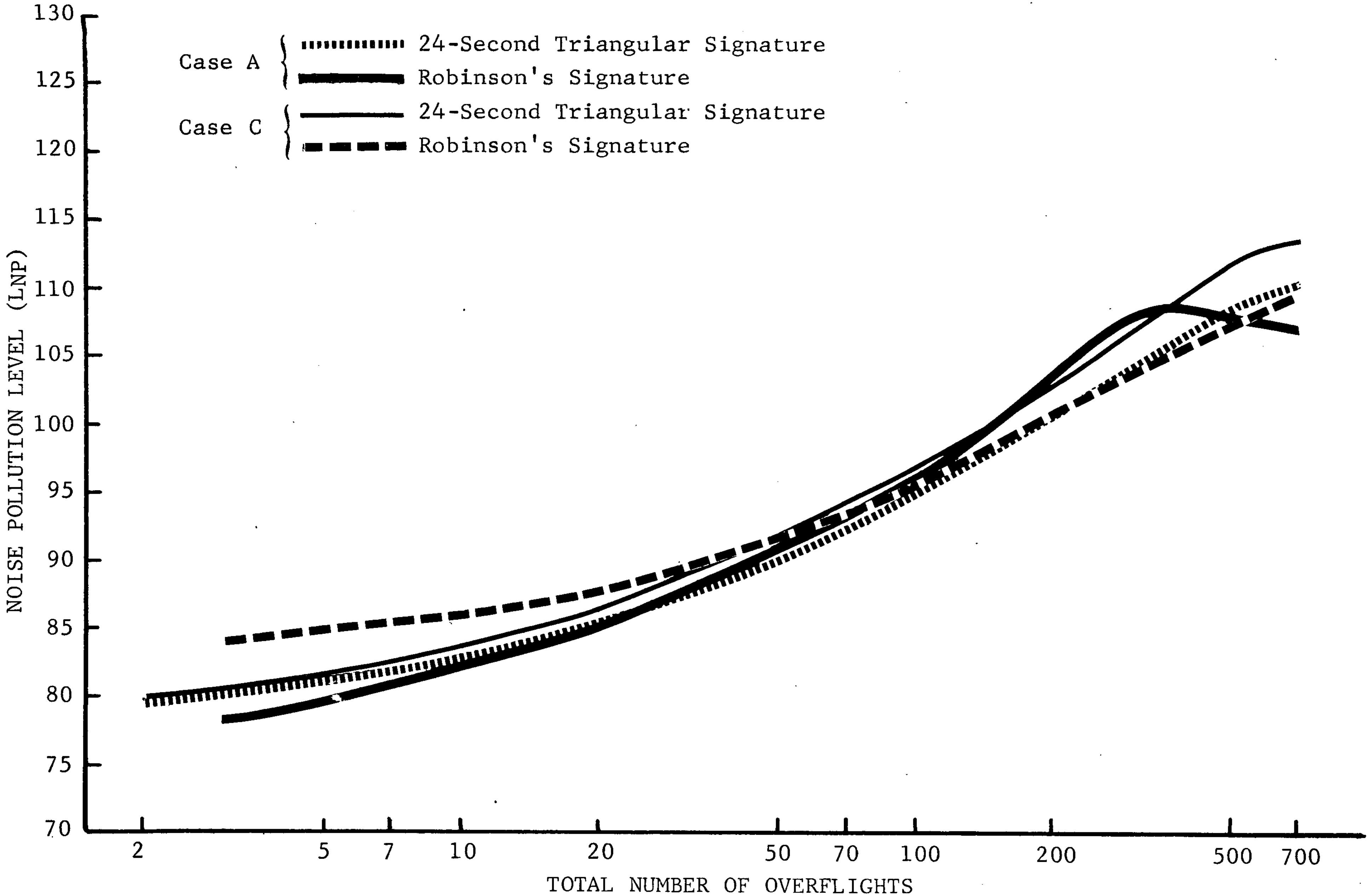


FIGURE A.5 - EFFECT OF PEAK LEVEL CONFIGURATION ON L_{NP}
(Case A and Case C; 70-85 PNdB Ambients)

A3.2 Effect of Background Levels

Figure A.6 shows the effect of background levels for 24-second triangular signatures and for Robinson's signature. The TRACOR curves are the average L_{NP}'s for Case A, Case B, and Case C, each calculated for the given number of total overflights and the background level indicated. The curves for Robinson's signature are from Figure 7 of his report, where they are labeled "72.5" and 82.5." (It is not clear from the AERO report what the "72.5" and "82.5" curves really represent; the description of their formation seems to have been omitted. The curves possibly represent the mean of the three cases for background levels of 70 and 75 PNdB, and for 80 and 85 PNdB, respectively. The TRACOR curves are for the actual background levels of 72.5 and 82.5 PNdB averaged over the three cases.) The two pairs of curves are quite similar, but with differences for high numbers of overflights observed previously.

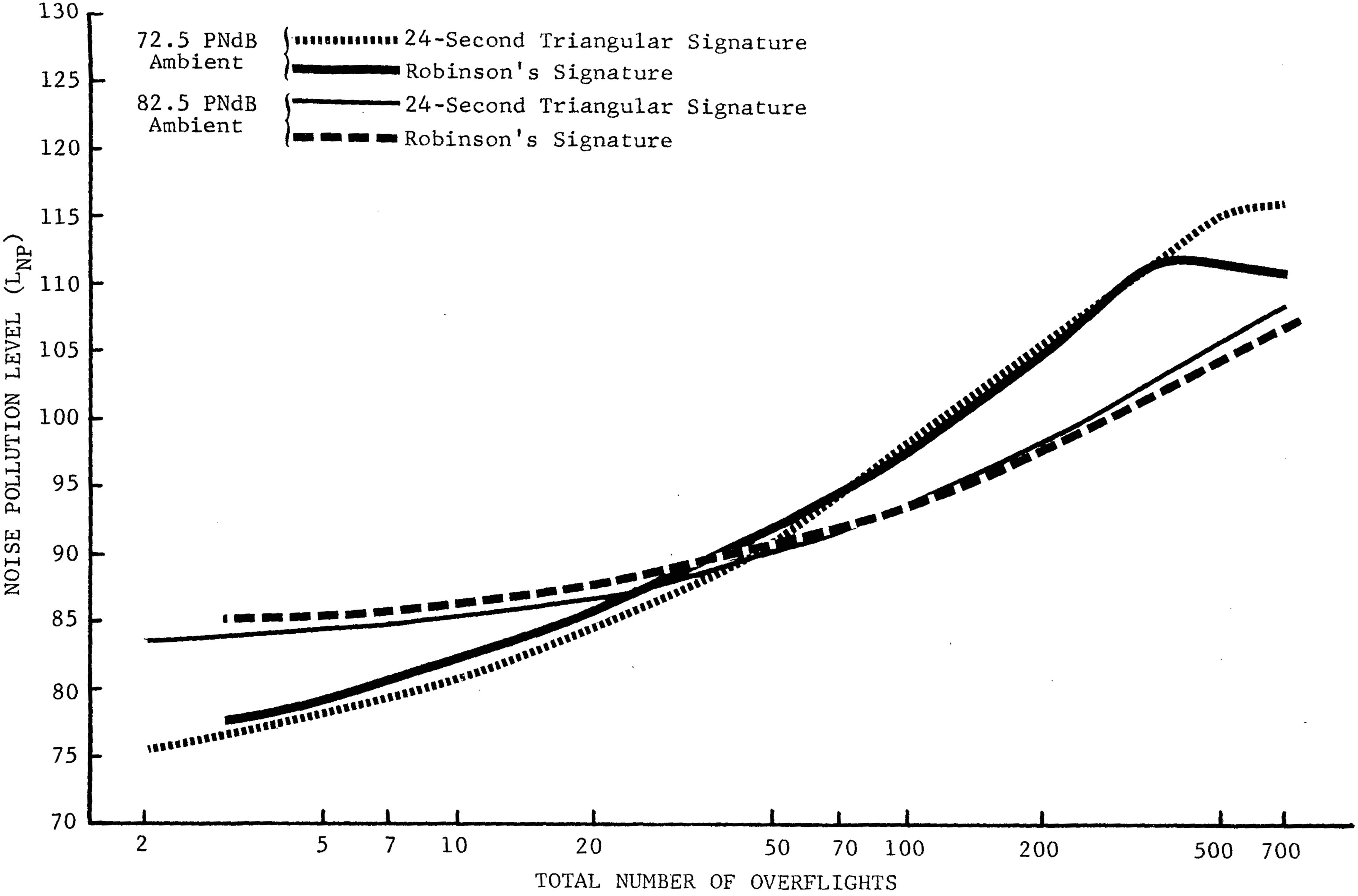


FIGURE A.6 - EFFECT OF BACKGROUND LEVEL ON L_{NP}
(Averaged for Cases A, B, and C;
70-85 PNdB Ambients)

TRACOR

A3.3 Effect of Background Fluctuations

Figure A.7 shows the effect of fluctuation in background levels on Case A (with 24-second triangular signatures). The levels which occur in the absence of aircraft are assumed to be normally distributed with a standard deviation σ_A. Robinson's AERO report examples assumed $\sigma_A = 0$. The effect of increasing σ_A is dramatic. Assuming fluctuations with σ_A equal to 10 percent of the median background level, L_{NP} increases by as much as 25 units, while a σ_A of 5 percent of the median background level increases L_{NP} by as much as ten units.

A realistic estimate of σ_A may be derived from regression equations for L_{90} and L_{10} contained in the Medford study (Serendipity, 1971). An estimate of the standard deviation of levels measures in typical communities is

$$\sigma = 11.21 - 0.1211\ L_{50}$$

If it is assumed that aircraft noise affected these results negligibly (a reasonable assumption since the study was primarily a surface vehicle noise survey, and most sites had few or no aircraft overflights), and that

$$\text{PNdB} \doteq \text{dBA} + 12.6$$

then

$$\sigma_A = 12.74 - 0.1211\ A$$

where A = median background level in PNdB.

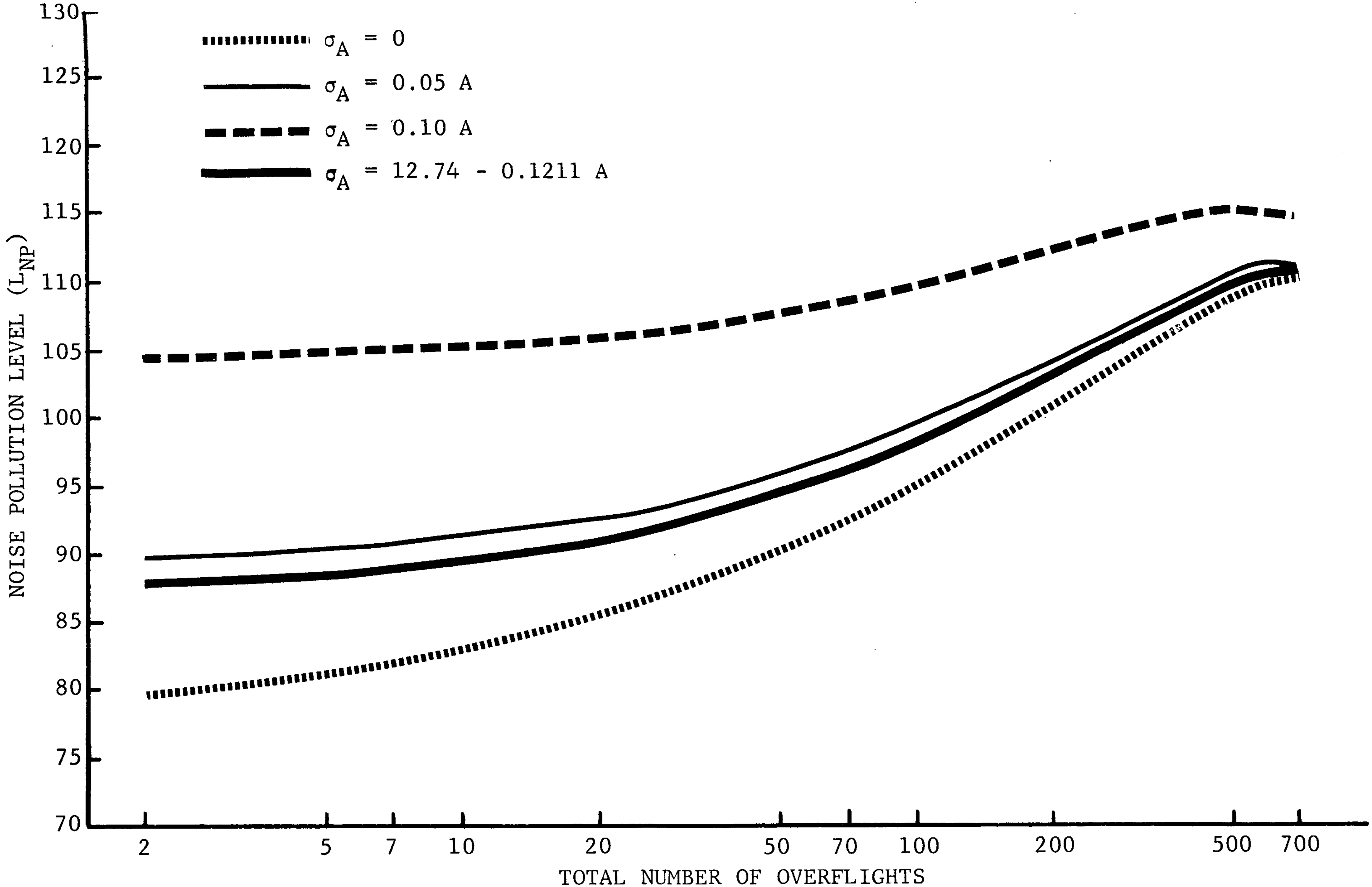


FIGURE A.7 - EFFECT OF BACKGROUND LEVEL FLUCTUATIONS ON L_{NP}
(Case A; 70-85 PNdB Ambients; 24-Second
Triangular Signature)

The L_{NP} curve generated using this approximation is also shown in Figure A.7.

In order to estimate the effect of the assumption $\sigma_A = 0.10$ A which was used for calculation of respondents' L_{NP} values in the primary analysis in this report, the curves of Figure A.7 were recomputed using ambient levels observed in the acoustical survey. Figure A.8 shows the results for Case A, where the data are averaged over median background levels of 50, 55, 60, 65, 70, and 75 PNdB. The curves represent the same assumptions about σ_A as those in Figure A.7 ($\sigma_A = 0$, $\sigma_A = 0.05$ A, $\sigma_A = 0.10$ A, and $\sigma_A = 12.74 - 0.1211$ A). The range of number of overflights in this study is 20 to 200. In this range, the difference in L_{NP} between the curves generated by $\sigma_A = 0.10$ A and $\sigma_A = 12.74 - 0.1211$ A is from three to two L_{NP} units. Thus for Case A and for the range of operations and the range of ambients observed, the difference between these two assumptions regarding σ_A is nearly constant. This indicates that the approximation used is adequate.

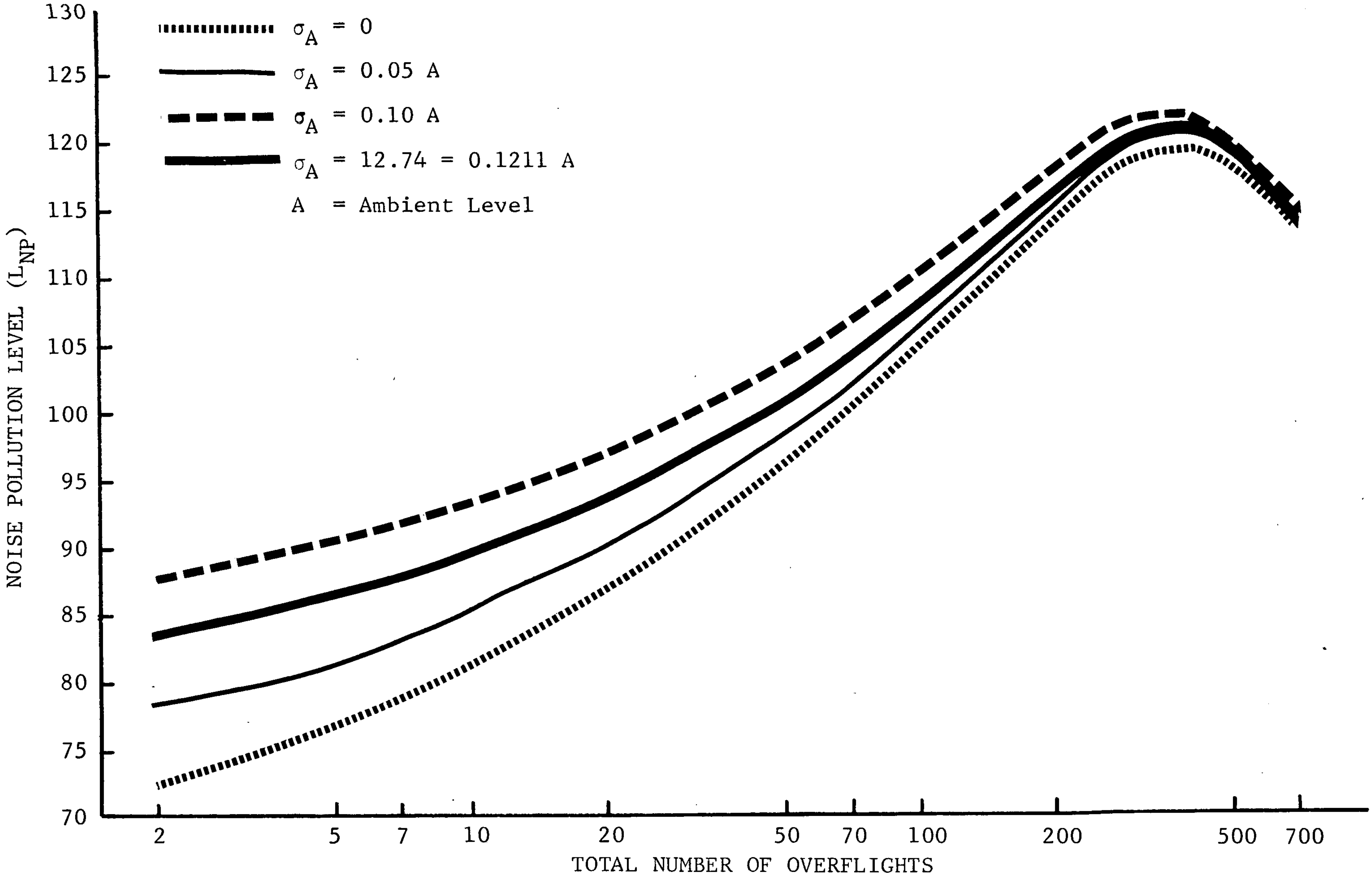


FIGURE A.8 - EFFECT OF BACKGROUND LEVEL FLUCTUATIONS ON L_{NP}
(Case A; 50-75 PNdB Ambients; 24-Second
Triangular Signature)

APPENDIX B

Survey Questionnaire

Form D (Revised)

OFFICE USE ONLY

No. ________

Rcd. ____ / ____

Log ________

Validity P/R/ ________

Grade ________

PROGRAM
IN
COMMUNITY STUDIES
1970
FORM D (R)

TRACOR Environmental & Physical Sciences Division

FORM APPROVED

BUDGET BUREAU NO. 104-S70002

QUESTIONNAIRE (FORM D--REVISED)

Interviewer Name ______________________________ Number __________

City ____

Date of Interview ______ / ______ / ______
Month Day Year

Time Interview Began _______ Ended _______ Total Minutes _____

Census Tract __________ __________ Census Block __________

(NOTE TO INTERVIEWER: YOUR INSTRUCTIONS ARE IN CAPITAL LETTERS AND ENCLOSED IN PARENTHESES. DO NOT READ THESE INSTRUCTIONS TO RESPONDENT.)

(1). (INTRODUCE SELF)

(2). (INDICATE SUBJECT AND PURPOSE OF STUDY, FOR EXAMPLE:)

I am a research interviewer working on a study of community issues here in (NAME OF CITY). My job is to help conduct a survey of the attitudes and opinions of the residents of this city and this neighborhood regarding common issues. Any answers you give me will be confidential, and they will be used to help plan future community improvements.

(3) (HAND RESPONDENT OPINION THERMOMETER.)

The two sides of this card have "opinion thermometers" which we will use in several questions to estimate how you feel about certain things. For example, turn to Side I. On the left is a Frequency Scale to estimate How Often. For practice, let's estimate how often you go to the movies. Think of how often you go. If you rarely go to the movies, you would say "zero". On the other hand, if you went very often, you would say "four" or perhaps "three". If you sometimes go to the movies, you would say "one" or "two". If you go to the movies about as often as your friends or acquaintances you would have a score of "two" - the average in most cases.

Now, how often would you say you go to the movies? (CIRCLE NUMBER) 0 1 2 3 4

The other scales (How Much and How Good) are used in the same way. Remember that "three" or "four" mean Very Much or Very Good, "zero" means Very Poor or Not at All, and "two" means About Average.

Now we will start.

1. How long have you lived in (NEIGHBORHOOD)? ______________ (RECORD IN YEARS)

   DK _____ NR _____

2. How long have you lived in (CITY)? ______________ (RECORD IN YEARS)

   DK _____ NR _____

Now, at the present time, what are some of the things you like or don't like about living in this neighborhood - things that you feel are advantages and make this a good place to live, or disadvantages - things that you feel are unpleasant?

3. What are the advantages, if any?

(RECORD ANSWER VERBATIM IN SPACE BELOW)

Now, most neighborhoods have some things about them people dislike.

4a. What are the disadvantages of living in this neighborhood, if any?

(RECORD ANSWER VERBATIM, RETAINING ORDER OF MENTION)

(NUMBER ORDER OF MENTION IN COLUMN 4A)

(IF VERBATIM ANSWERS DO NOT "FIT" CATEGORIES, RECORD ANSWERS IN SPACES BELOW "AIRCRAFT NOISE")

DISADVANTAGES

1. ____________________

2. ____________________

3. ____________________

4. ____________________

DK_____ NR_____

Here is a list of things some people dislike the most about where they live.

(INTRODUCE CARD 1, HAND TO RESPONDENT)

4b. Which one thing on this list (ADD ANY MENTIONED IN 4a) do you dislike the most about where you live?

(MARK ONE THING DISLIKED THE MOST IN COLUMN 4B)

4A		4B	4C	DK	NR
	NOTHING DISLIKED				
	INCONVENIENT LOCATION		0 1 2 3 4		
	EXPENSIVE PLACE TO LIVE		0 1 2 3 4		
	UNSAFE PLACE TO LIVE		0 1 2 3 4		
	RUN-DOWN NEIGHBORHOOD		0 1 2 3 4		
	POOR FACILITIES		0 1 2 3 4		
	UNFRIENDLY NEIGHBORS		0 1 2 3 4		
	DISLIKE FOR A CERTAIN HOUSE		0 1 2 3 4		
	NO PRIVACY		0 1 2 3 4		
	OTHER NOISE		0 1 2 3 4		
	AIRCRAFT NOISE		0 1 2 3 4		
			0 1 2 3 4		
			0 1 2 3 4		
			0 1 2 3 4		
			0 1 2 3 4		

(TAKE BACK CARD 1)

4c. Using the Opinion Thermometer, how much do you dislike this one thing? (CIRCLE NUMBER IN COLUMN 4C)

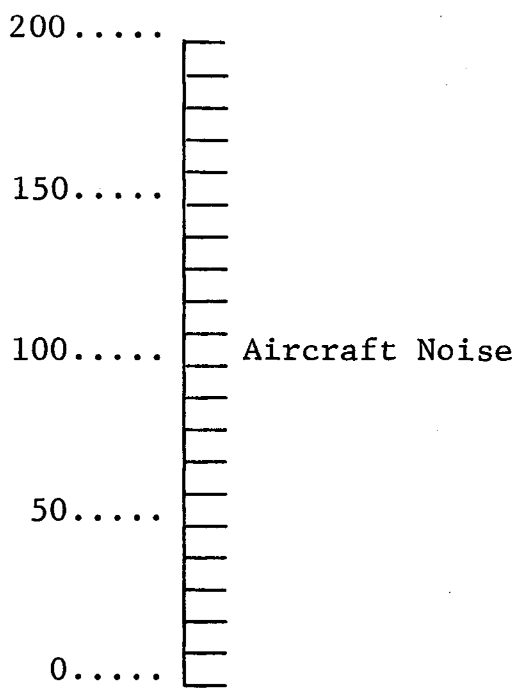
(GO TO 4D)

→ (SKIP TO 5A)

4d. In order to find out how important (Most Disliked Thing) is in comparison to other things in the neighborhood, we want you to locate several items on a scale. (HAND R. CARD 2.) The idea is to pick a number on the scale which shows the relative importance of (Most Disliked Thing) to you.

(IF AIRCRAFT NOISE IS MOST DISLIKED THING):
Notice that Aircraft Noise is located at the number "100." What number below it do you feel best fits the next most disliked thing in your neighborhood?
(WRITE IN LOCATION OF NEXT MOST DISLIKED THING) (TAKE BACK CARD 2)
(GO TO 5C)

(IF AIRCRAFT NOISE IS <u>NOT</u> MOST DISLIKED THING):
For example, Aircraft Noise is located at the number "100." What number above it do you feel best fits (Most Disliked Thing) in comparison to Aircraft Noise?
(WRITE IN LOCATION OF MOST DISLIKED THING) (TAKE BACK CARD 2)
(GO TO 5C)



(IF NOTHING DISLIKED, ASK:)

5a. In the past was there ever anything you disliked about living here?

YES _____; NO _____ (IF NO, DK OR NR GO TO QUESTION 8)
DK _____; NR _____

5b. (IF YES): What was that? ______________________________

____

5c. How many times in an average week do/did you discuss (MOST DISLIKED THING OR ONE THING DISLIKED IN THE PAST) with friends, neighbors, or relatives?

(CIRCLE NUMBER) 0 1 2 3 4 More than 4 DK___ NR___

5d. Do/did you yourself ever feel like doing something to improve this situation? For example, do/did you feel like: (READ LIST, MARK "YES" OR "NO")

	5D				5E			
	YES	NO	DK	NR	YES	NO	DK	NR
DISCUSSING IT WITH SOMEONE								
TELEPHONING OR WRITING TO AN OFFICIAL								
SIGNING A PETITION								
VISITING AN OFFICIAL								
ATTENDING A MEETING ABOUT IT								
HELPING TO SET UP A COMMITTEE TO DO SOMETHING ABOUT IT								
WRITING A LETTER TO THE EDITOR								
FILING A SUIT								
OTHER								

(IF RESPONDENT ANSWERS "NO" TO ALL ITEMS IN 5D, GO TO 5F)

5e. Did you (or your family) actually do any of these things?

YES _____; NO _____ DK _____ NR _____

(IF YES): Which one(s)? (MARK IN COLUMN 5E)

What happened? ______________________________

____

____

(IF NO): Why is that? That is, why did you decide not to do anything?

____

____

5f. Has any local organization ever asked you to do any of these things?

YES _____; NO _____; DK _____; NR _____

5g. What do you think are/were the chances of an organization improving or reducing this situation?

VERY GOOD ___; GOOD ___; FAIR ___; NOT VERY GOOD ___;

POOR ___; DK ___; NR ___

6. Do/did you happen to know who or where to call if you wanted to complain?

YES ____; NO _____; DK _____; NR _____

7. In your own opinion, how much are/were your neighbors bothered by this situation? Use the Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK____ NR____.

(ASK EVERYONE):

8. Here is a list of sounds which sometimes bother people. Most people hear these sounds somewhere, not necessarily in their own homes. Use the Opinion Thermometer to rate how much each sound bothers you when you do hear it.

(READ LIST AND CIRCLE NUMBER FOR EACH SOUND)

SOUNDS	RATING	DK	NR
WALKING ON GRITTY FLOORS	0 1 2 3 4		
MUSICAL INSTRUMENTS IN PRACTICE	0 1 2 3 4		
BANGING DOORS	0 1 2 3 4		
AIR HAMMERS	0 1 2 3 4		
DRIPPING WATER	0 1 2 3 4		
WHISTLING	0 1 2 3 4		
CHALK SCRAPING ON A BLACKBOARD	0 1 2 3 4		
NEIGHBOR'S RINGING TELEPHONE	0 1 2 3 4		
PEOPLE WALKING ON THE FLOOR ABOVE	0 1 2 3 4		
CHAIRS SCRAPING ON THE FLOOR	0 1 2 3 4		
NEIGHBORS LAUGHING OR QUARRELING	0 1 2 3 4		
TYPEWRITERS	0 1 2 3 4		

9a. I will now read a number of noises heard in different neighborhoods. Which ones do you hear in this neighborhood ?

(READ LIST TO RESPONDENT, CHECKING WHETHER NOISE IS HEARD OR NOT)

(FINISH 9a BEFORE ASKING 9b)

9b. Of those that you hear, how much are you bothered or annoyed? Use the Opinion Thermometer.

(CIRCLE NUMBER IN COLUMN 9b ONLY FOR THOSE NOISES HEARD)

(FINISH 9b BEFORE ASKING 9c)

9c. Some people are more aware of noise than others. How much is each noise that you hear noticeable to you; that is, how much attention do you pay to each one? Please use the Opinion Thermometer.

(CIRCLE NUMBER IN COLUMN 9c)

(PROBE TO SEE IF RESPONDENT WOULD NOW LIKE TO INCLUDE MORE NOISES AS HEARD)

	9a HEARD				9b ANNOYS			9c NOTICES		
			DK	NR		DK	NR		DK	NR
AUTOS	YES	NO			0 1 2 3 4			0 1 2 3 4		
NEBH. CHILDREN	YES	NO			0 1 2 3 4			0 1 2 3 4		
AIRCRAFT	YES	NO			0 1 2 3 4			0 1 2 3 4		
DOGS/PETS	YES	NO			0 1 2 3 4			0 1 2 3 4		
PEOPLE	YES	NO			0 1 2 3 4			0 1 2 3 4		
CYCLES/HOT RODS	YES	NO			0 1 2 3 4			0 1 2 3 4		
TRAINS	YES	NO			0 1 2 3 4			0 1 2 3 4		
SIRENS	YES	NO			0 1 2 3 4			0 1 2 3 4		
CONSTRUCTION	YES	NO			0 1 2 3 4			0 1 2 3 4		
LAWN MOWERS	YES	NO			0 1 2 3 4			0 1 2 3 4		
GARBAGE COLLECTION	YES	NO			0 1 2 3 4			0 1 2 3 4		
SONIC BOOMS	YES	NO			0 1 2 3 4			0 1 2 3 4		
TRUCKS	YES	NO			0 1 2 3 4			0 1 2 3 4		
OTHER (SPECIFY)	YES	NO			0 1 2 3 4			0 1 2 3 4		
NO NOISES HEARD	YES									

→ (SKIP TO QUESTION 20a)

10. When you see or hear airplanes overhead, how often do you feel they are flying too low for the safety of residents in the area? Use Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK____; NR____

11. When you see or hear airplanes overhead how often do you feel there is some danger that they might crash nearby? Use Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK____; NR____

12. What times of the day do you particularly notice aircraft noise? (CHECK WHETHER WEEKDAYS OR WEEKENDS)

	Morning		Afternoon		Evening		Night	
	6-9	9-12	12-3	3-6	6-9	9-12	12-3	3-6
WEEK-DAYS								
WEEK-ENDS								
DK								
NR								

All the time ____

No particular time ____

13. What days of the week do you particularly notice aircraft noise?

	Sun.	Mon.	Tues.	Wed.	Thur.	Fri.	Sat.
YES							
NO							
DK							
NR							

Every day _____

No particular day _____

14. How often do you notice smoke, fumes, oil dropout, or landing lights from overflying airplanes? Use the Opinion Thermometer. (MARK IN COLUMN 14 BELOW)

	14	15
SMOKE	0 1 2 3 4 DK NR	0 1 2 3 4 DK NR
FUMES	0 1 2 3 4 DK NR	0 1 2 3 4 DK NR
OIL DROPOUT	0 1 2 3 4 DK NR	0 1 2 3 4 DK NR
LANDING LIGHTS	0 1 2 3 4 DK NR	0 1 2 3 4 DK NR

IF "NONE," (ZERO ON ALL ITEMS) FOR QUESTION 14 → 16.

15. How much does (EACH ITEM IN QUESTION 14 THAT IS NOTICED) annoy you? Use the Opinion Thermometer. (MARK IN COLUMN 15 ABOVE)

16. Were you fully aware of the noise from aircraft operations in this neighborhood before coming here?

YES _____; NO _____; DK _____; NR_____

17. How much would you say aircraft operations have increased in this area in the past five years? Use the Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK_____; NR______

18. Would you say that you have learned to live with aircraft noise the way it is now?

YES_____; NO_____; UNDECIDED_____; NR_____

19a. If this area were to receive more noise from aircraft, how much of this noise do you think you could learn to live with?

TWICE AS MUCH_____; THREE TIMES AS MUCH_____;

FOUR TIMES AS MUCH_____; NO MORE AT ALL_____; UNDECIDED_____

NR_____

19b. Which could you learn to live with, aircraft noise which occurs frequently but not very loud, or aircraft noise which occurs infrequently but loud?

FREQUENTLY BUT NOT VERY LOUD_____

INFREQUENTLY BUT LOUD_____

UNDECIDED_____

NR_____

20a. I will now read a number of daily activities. Which of these are disturbed by aircraft noise in your own situation here? (READ LIST BELOW AND CHECK "YES," "NO," "DK," OR "NR")

	20a DISTURBED				20b BOTHERED		
			DK	NR		DK	NR
RELAXING/RESTING INSIDE	Yes	No			0 1 2 3 4		
RELAXING OUTSIDE	Yes	No			0 1 2 3 4		
CHILDREN SLEEPING/NAPPING	Yes	No			0 1 2 3 4		
CONVERSATION	Yes	No			0 1 2 3 4		
TELEPHONE CONVERSATION	Yes	No			0 1 2 3 4		
GOING TO SLEEP	Yes	No			0 1 2 3 4		
LISTENING TO RECORDS/TAPES	Yes	No			0 1 2 3 4		
LISTENING TO RADIO/TV	Yes	No			0 1 2 3 4		
WATCHING TV	Yes	No			0 1 2 3 4		
LATE SLEEP	Yes	No			0 1 2 3 4		
READING OR CONCENTRATION	Yes	No			0 1 2 3 4		
EATING	Yes	No			0 1 2 3 4		
OTHER	Yes	No			0 1 2 3 4		
NONE	Yes						

20b. (OF THOSE THAT ARE DISTURBED): How much are you bothered? Use the Opinion Thermometer. (CIRCLE NUMBER IN COLUMN 20b)

21. How often do airplanes make the house (building) vibrate or make the windows rattle? Use the Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK_____ NR_____

22. Who would you say controls the flight operations of aircraft around here?

____

DK_____NR_____

23a. Would you say the value of land in this area has gone up, gone down, or not changed in the past five years?

NOT CHANGED _____ DK _____
GONE DOWN _____ NR _____
GONE UP _____

23b. (IF CHANGED): Has the airport or aircraft operations been responsible for this change in any way?

YES_____; NO_____

24a. (IF LAND VALUE HAS GONE DOWN IN QUESTION 23a): If a person felt that aircraft operations were reducing the value of his property, do you think he would be able to recover damages through an appeal to the proper authorities?

YES_____; NO_____; DK_____; NR_____

24b. (IF NO): Why not?______________________________

____

____

25. Do you know of anyone who has moved out of this area because of aircraft noise?

YES_____; NO_____; DK_____; NR_____

(IF YES): How many?______________________________

	YES	NO	DK	NR
26. Do you think that jet engines could safely be made quieter with mufflers or other devices like that?	___	___	___	___
27. Is it necessary for jet planes to sit on the ends of runways and roar their engines?	___	___	___	___
28. Do jet planes have to takeoff and land on certain runways because of weather conditions?	___	___	___	___
29. Do all airplanes have to circle the airport before landing?	___	___	___	___
30. Do jet planes have to fly at lower altitudes depending on weather conditions?	___	___	___	___

Now we have a series of True-False questions :

	TRUE	FALSE	DK	NR
31. Politics in this country are controlled by only a handful of persons or families.	___	___	___	___
32. Most local government officials are honest.	___	___	___	___
33. Most people don't care what happens to the next fellow.	___	___	___	___
34. Nowadays a person has to live pretty much for today and let tomorrow take care of itself.	___	___	___	___
35. Any devices designed to reduce aircraft noise will prove too costly to be practical.	___	___	___	___
36. Aircraft designers are doing all they can to produce quieter engines.	___	___	___	___

		TRUE	FALSE	DK	NR
37.	The airport is operated in such a way as to serve the best interests of the entire city.	____	____	__	__
38.	A person should not have to put up with aircraft noise.	____	____	__	__
39.	Community leaders are doing all they can possibly do to reduce aircraft noise in this city.	____	____	__	__
40.	Airport authorities are doing all they can possibly do to reduce aircraft noise.	____	____	__	__
41.	Aircraft noise is rather pleasant and soothing.	____	____	__	__
42.	This city can be proud of the services its airport provides to both the community and to its clients.	____	____	__	__
43.	The advantages to the community from having a large airport far outweigh any disadvantages.	____	____	__	__
44.	Airport authorities probably are not very much concerned with what the average citizen thinks about them.	____	____	__	__
45.	Airport authorities try to avoid sending many flights over heavily populated areas.	____	____	__	__
46.	Most business firms and leaders in this city are simply pawns of different governmental officials and agencies.	____	____	__	__
47.	It is not likely for an airplane to crash in this area.	____	____	__	__
48.	The defense of our country is not possible without military aircraft.	____	____	__	__
49.	Most individuals and groups that protest about airplane noise do so because they are genuinely interested in eliminating the annoyance to themselves and others.	____	____	__	__

	TRUE	FALSE	DK	NR
50. People who complain about airplane noise are only trying to gain personal fame and advancement.	____	____	__	__
51. Most people are sometimes frightened by aircraft noise.	____	____	__	__
52. Most people are often frightened by aircraft noise.	____	____	__	__
53. Airplane noise can damage a person's health.	____	____	__	__
54. Airline companies will do nothing about airplane noise unless they are forced to.	____	____	__	__
55. Air transportation is the only practical way of long-distance travel.	____	____	__	__

56. Do you think that a jet plane could safely land at less than full power?

YES_____; NO_____ DK_____; NR_____

57. Have you flown as a passenger on a jet plane once, twice or more, or never?

ONCE_____; TWICE OR MORE_____; NEVER_____

58a. Do you think air travel is as safe as cars?

YES_____; NO_____; DK_____; NR_____

→ 58b. (IF YES): Is it safer?

YES_____; NO_____; DK_____; NR_____

59. Do you think pilots consider the people below them when they take off and land?

YES_____; NO_____; DK_____; NR_____

60. Do you think pilots try to hold down the noise made by their planes?

YES_____; NO_____; DK_____; NR_____

61. Do you think that noise made by planes at the terminal and while on the ground could be reduced?

YES_____; NO_____; DK_____; NR_____

62. Who is responsible for reducing the noise from airplanes? The pilot, the airport authorities, the manufacturers, or who? (CHECK MORE THAN ONE, IF NECESSARY)

PILOT_____; AIRPORT AUTHORITIES_____; MANUFACTURER_____;

OTHERS____

DK_____

63a. What kinds of clubs or organizations do you work with or participate in? For example: educational, recreational, political, social, business, church, fraternal, or any other such groups.

63b	63c	63d	63e	63f		
ORGANIZATION	PURPOSE	MEETS	ATTENDS	OFFI-CER	COMMIT-TEE	MEMBER ONLY

(IF INVOLVED IN ONE OR MORE ORGANIZATIONS):

63b. What are these organizations?
(RECORD IN COLUMN 63b)

63c. What is the purpose of these organizations? For example, discussions of current events, service to the community, brotherhood, socializing, etc.?
(RECORD IN COLUMN 63c)

63d. How many times did the organization(s) meet in the last year?
(RECORD IN COLUMN 63d)

63e. How many times did you attend meetings in the last year?
(RECORD IN COLUMN 63e)

63f. Were you or are you now an officer or committee member in any of these organizations?
(RECORD IN COLUMN 63f)

(IF ANY ORGANIZATION INTERESTED IN AIRCRAFT NOISE, ASK QUESTION 64.)

64. Do you think they could succeed if they tried to do somethink to improve or reduce aircraft noise?

YES_____; NO_____; DK_____; NR_____

65. How many people including yourself, any children, and relatives live here?__________________ DK_____ NR_____

66a. Who is the head of the household in this house?

__________________ __________________ DK_____ NR_____

66b. Is he (she) employed now, at the present time?

YES_____; NO_____; DK_____; NR_____

66c. What sort of work does (HEAD OF HOUSEHOLD) do, that is, what does he (she) do on the job?

OCCUPATION_____ ________________________________

DK_____ NR_____

(IF RESPONDENT IS NOT THE HEAD OF THE HOUSEHOLD, ASK QUESTION 67, OTHERWISE GO TO QUESTION 68a)

67a. Do you have a job away from home?

YES_____; NO_____; DK_____; NR_____

67b. (IF YES): What sort of work do you do?
OCCUPATION________________________________

67c. (IF NO, INDICATE STATUS; i.e., HOUSEWIFE, STUDENT, RETIRED, ETC.)

HOUSEWIFE_____; STUDENT_____; RETIRED_____; DISABLED_____;
OTHER, SPECIFY________________________________

68a. Are you or anyone in your family employed at this time at an airport or by an airline company?

YES_____; NO_____; DK_____; NR_____

68b. (IF YES): What type work does he (she) do? (MECHANIC, CLERK, MANAGER, ETC.)

____

____

68c. Have you or anyone in your family ever worked or been employed at an airport or by an airline company?

YES_____; NO_____; DK_____; NR_____

69. Here is a card with typical family incomes. (HAND RESPONDENT CARD 3) Which category most nearly represents your total family income -- from all sources and before taxes?

(CIRCLE NUMBER) 1 2 3 4 5 6 7 8

REFUSED TO ANSWER_________ DK_________

(TAKE BACK CARD 3)

70a. What is the highest grade of school head of household/you has/have completed?

GRADE SCHOOL (1-8)	_____
HIGH SCHOOL (9-12)	_____
1-3 YEARS COLLEGE	_____
COLLEGE GRADUATE	_____
MORE THAN 4 YEARS COLLEGE	_____
DK	_____
NR	_____

70b. In which age category does/do head of household/you belong?

20-29 ___

30-39 ___

40-49 ___

50-59 ___

60-69 ___

70+ ___

71a. Do you own your home or are you renting?

OWN_____; RENT_____; DK_____; NR_____

71b. (IF OWN): How much would a home like this rent for in this neighborhood, not including furniture and utilities?

UNDER $75____; $75-$124_____; $125-$174_____; $175-$224_____;
$225-$274_____; $275-$324_____; $325-$374_____; $375-$424_____;
$425 OR MORE_____

71c. (IF RENT): Approximately how much do you pay for rent?

UNDER $75_____; $75-$124_____; $125-$174_____; $175-$224____;
$225-$274_____; $275-$324____; $325-$374_____; $375-$424____:
$425 OR MORE_____

72. How many times have you moved within the past ten years?

(CIRCLE NUMBER) 0 1 2 3 4 5 6 7 8 9 or more DK__ NR__

73. How often do you visit or drop in on relatives or friends? Use the Opinion Thermometer.

(CIRCLE NUMBER) 0 1 2 3 4 DK_____ NR _____

74. Do you have a fireplace?

YES_____; NO_____; DK_____; NR_____

75. Do you have central air-conditioning, window air-conditioning, evaporative coolers, or fans?

YES_____; NO_____; DK_____; NR_____

76. Does the building have insulation in the walls or between the ceiling and the roof?

NO _____
WALLS _____
ROOF _____
BOTH _____
DK _____
NR _____

77. Are your windows made of single or multiple thicknesses of glass?

SINGLE _____
MULTIPLE _____
BOTH _____
OTHER _____
DK _____
NR _____

78. Does the building have storm windows?

YES_____; NO_____; DK_____; NR_____

79. Does the building have an attic or a space between the ceiling and the roof?

YES_____; NO_____; DK_____; NR_____

80. What is the outside of this building made of?

WOOD OR STUCCO	_____
MASONRY (BRICK, STONE, CEMENT, ETC.)	_____
WOOD AND STUCCO/MASONRY	_____
ASBESTOS/SHINGLE	_____
OTHER	_____
DK	_____
NR	_____

81. About how thick are the exterior walls?

LESS THAN SIX INCHES	_____
SIX TO TWELVE INCHES	_____
MORE THAN TWELVE INCHES	_____
DK	_____
NR	_____

82. How many windows and glass doors are there?

______________ DK_____ NR_____

83. How many outside doors (excluding large glass doors) do you have?

__________ (RECORD NUMBER) DK_____ NR _____

(IF DWELLING UNIT IS OTHER THAN A SINGLE-UNIT HOUSE I.E., AN APARTMENT, DUPLEX, ETC., ASK QUESTION 85):

84. How many walls are exposed to the outside?

__________ DK_____ NR_____

85. (DOES THE RESPONDENT LIVE ON THE TOP FLOOR OF A MULTI-UNIT STRUCTURE?)

(YES__________; NO_______)

86. In case I've forgotten anything and we need to call, what number should we call, and what would be the best time of day?

NUMBER:________________ BEST TIME:__________________________

87. May I please have your name?

____

88. What is your address here?

____

(RECORD NAME AND ADDRESS ON COVER)

89. (INTERVIEWER: SEX OF R)

Male ___ Female ___

90. (INTERVIEWER: ETHNIC GROUP OF R)

A___ N ___ S ___ O ___

APPENDIX C

Construction of Social Variables

1. Variable: Adaptability
2. Range: 0-1
3. Categories: none
4. Questionnaire items:

   24A. (p. 19) If this area were to receive more noise from aircraft, how much of this noise do you thing you could learn to live with?
   TWICE AS MUCH___, THREE TIMES AS MUCH___,
   FOUR TIMES AS MUCH___, NO MORE AT ALL___,
   UNDECIDED___, NR___.

5. Construction:

   If the respondent indicated NO MORE AT ALL, UNDECIDED, or NR, he was given the score of zero (0). If the respondent indicated TWICE AS MUCH, or more, the score of one (1) was given.

1. Variable: Annoyance G
2. Range: 0-45
3. Categories: 0-9 (low), 10-21 (medium), 22-45 (high)
4. Questionnaire items:

   25A. (p. 20) I will now read a number of daily activities. Which of these are disturbed by aircraft noise in your own situation here? (READ LIST BELOW AND CHECK "YES," "NO," "DK," OR "NR.")

   25B. (p. 20) (OF THOSE THAT ARE DISTURBED): How much are you bothered? Use Opinion Thermometer.

5. Construction:

   Annoyance-G is a summated-ratings index composed of nine everyday activities: relaxing/resting inside, relaxing/resting outside, sleep, conversation, telephone conversation, listening to records/tapes, radio/TV interference, reading or concentration, and eating. From the list of items on page 15, an average of the items "children sleeping/napping," "going to sleep," and "late sleep" was used for the item "sleep." An average of "listening to radio/TV" and "watching TV" was used for the item "radio/TV interference." In order to form the total index, each 0-to-4 scale was converted to 1-to-5, "DK" and "NR" were coded zero (0), and all scores summed.

1. Variable: Distance
2. Range: 0-10
3. Categories: 1.0-1.9, 2.0-2.9, 3.0-3.9, 4.0-4.9, 5.0-5.9, 6.0-6.9, 7.0-7.9, 8.0-8.9, 9.0-9.9, 10.0+
4. Questionnaire item:
   (Calculated from maps)
5. Construction:
   Distance was calculated from the end of the runway to the block address of the respondent. Measurement was to the nearest tenth-mile.

1. Variable: Fear
2. Range: 0-10
3. Categories: 0-3 (low), 4-6 (medium), 7-10 (high)
4. Questionnaire items:

   14. (p. 17) When you see or hear airplanes overhead, how often do you feel they are flying too low for the safety of residents in the area? Use Opinion Thermometer. 0 1 2 3 4 DK_ NR_

   15. (p. 17) When you see or hear airplanes overhead how often do you feel there is some danger that they might crash nearby? Use Opinion Thermometer. 0 1 2 3 4 DK_ NR_

5. Construction:
   "Fear" is formed by converting 0-to-4 scale to 1-to-5, coding "DK" and "NR" zero, and summing for both items.

1. Variable: Importance
2. Range: 0-5
3. Categories: none
4. Questionnaire items:
   48. (p. 23) This city can be proud of the services its airport provides to both the community and to to its clients.
   TRUE___ FALSE___
   49. (p. 23) The advantages to the community from having a large airport far outweigh any disadvantages.
   TRUE___ FALSE___
   50. (p. 23) Airport authorities try to avoid sending many flights over heavily populated areas.
   TRUE___ FALSE___
   54. (p. 23) The defense of our country is not possible without military aircraft.
   TRUE___ FALSE___
   61. (p. 24) Air transportation is the only practical way of long-distance travel.
   TRUE___ FALSE___
5. Construction:
   For each item TRUE is coded zero (0) and FALSE is coded one (1). The sum of the five items constitutes the Importance index. This index measures the affective attractiveness of the airport or the airline industry to the respondent. A high score indicates a lack of importance to the respondent.

1. Variable: Noise Susceptibility
2. Range: 0-65
3. Categories: 0-9 (low), 10-29 (medium), 30-65 (high)
4. Questionnaire items:

   13A. (p. 15) I will now read a number of noises heard in different neighborhoods. Which ones do you hear in this neighborhood? (READ LIST TO RESPONDENT, CHECKING WHETHER NOISE IS HEARD OR NOT.)

   13B. (p. 15) Of those that you hear, how much are you bothered or annoyed? Use Opinion Thermometer.

5. Construction:

   The thirteen noise sources are autos, neighborhood children, aircraft, dogs/pets, people, motorcycles/hot rods, trains, sirens, construction, lawn mowers, garbage collection, sonic booms, and trucks. Each 0-to-4 scale was converted to 1-to-5, "DK" and "NR" were coded zero (0), and all items summed.

1. Variable: Misfeasance
2. Range: 0-4
3. Categories: none
4. Questionnaire items:

   42. (p. 22) Aircraft designers are doing all they can to produce quieter engines.
   TRUE___ FALSE___ DK___ NR___

   43. (p. 23) The airport is operated in such a way as to serve the best interests of the entire city.
   TRUE___ FALSE___ DK___ NR___

   45. (p. 23) Community leaders are doing all they can possibly do to reduce aircraft noise in this city.
   TRUE___ FALSE___ DK___ NR___

   46. (p. 23) Airport authorities are doing all they can possibly do to reduce aircraft noise.
   TRUE___ FALSE___ DK___ NR___

5. Construction:

   For each item TRUE is coded zero (0) and FALSE is coded one (1). The sum of the four items constitutes the Misfeasance index. This index measures the respondent's belief that those officials and authorities who are in a position to do something about the noise problem simply are not doing their job. Misfeasance is used rather than malfeasance since there is no intent to break the law or to do something illegal.

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