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NATIONAL AMBIENT NOISE SURVEY

JANUARY 1982

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16. ABSTRACT

The objectives, methodology, and results of a national survey of outdoor noise environments in urban residential areas are discussed. The objectives were to determine overall noise levels, source contributions, and patterns of spatial and temporal variation in these areas, along with the effect of three locational factors on these parameters. The survey employed a randomized site selection procedure, a stratified sampling strategy, and a multifaceted measurement protocol to meet these objectives. Results of the survey include a simple model which predicts Ldn in these areas, projections of nationwide noise impact, average source contributions and temporal noise level histories and average variations in noise level at different locations around residential units.

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None of this work would have been performed without the untiring support of Casey Caccavari of the EPA Noise Office State and Local Programs Division. His patience, and his attention, with so many other matters competing for them, are greatly appreciated.

Finally, tribute must be paid to the 124 households which permitted total strangers to conduct noise measurements around their homes. Their cooperation in this unique program reaffirms the good will and civic mindedness of the American people. One must hope that this work will in the long run reward that spirit with a more pollution free environment.

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EXECUTIVE SUMMARY

During 1980 and 1981, the Environmental Protection Agency (EPA) sponsored a survey of noise environments in urban residential areas. The purpose of the survey was to generate a statistically valid profile of noise levels and source contributions. This profile is intended to assist in the evaluation of the need for and effectiveness of noise control measures directed toward the urban residential environment.

The basic approach of the survey was to perform outdoor noise level measurements and source identifications at randomly selected residential units located in urban areas across the United States. The measurements were used to assess overall noise levels, source contributions, and temporal and positional variation in these quantities. The residential units were selected by means of a stratified sampling approach, with the stratifications based on urban area population, population density, and proximity to major roadways (traffic impact). The cell structure is summarized in table ES-1. Residential units highly impacted by aircraft noise were excluded from consideration.

The results show that 87 percent of the urban population are exposed to a day-night sound level (Ldn) over 55 dB, the threshold of impact for residential noise based on EPA criteria. The percent exposed to higher levels of Ldn is given in table ES-2.

Noise levels are usually higher at the front of residential units, with this tendency most pronounced in areas close to major roadways. Average differences in noise levels between the front, rear, and sides of the house are given in table ES-3.

Daily variation in Ldn is approximately 2 dB. Noise levels are not significantly different on weekend days, nor is there any other consistent pattern of daily variation.

Table ES-1. Summary of Categories Used to Define Sampling Cells

Parameter	Basis for Defining Categories	Number of Categories	Description of Categories
Urban Area Size	Urbanized area population (1970)	2	Large - ≥ 2,000,000 Medium/small - All others
Population Density	Urban zone population density (1970)	4	High - ≥ 4,500/ square mile Medium-high - 3,000-4,500 Medium-low - 1,500-3,000 Low - < 1,500
Traffic Impact	Distance from major roadways	2	High - Within 100 feet of an arterial or 300 feet of an interstate or freeway Low - All others
Aircraft Impact	Ldn contours around airports	2	High - Within Ldn = 65 dB contour Low - All others

Table ES-2. Populations Exposed to Critical Values of Ldn (Percent of Urban Population)

Ldn > 55 dB	87%
Ldn > 60 dB	53%
Ldn > 65 dB	17%
Ldn > 70 dB	2%
Ldn > 75 dB	<1%

Table ES-3. Differentials in Noise Levels by Side

Traffic Impact	Leq (Front)-Leq (Side)	Leq (Front)-Leq (Rear)
High	4 dB	9 dB
Low	3 dB	4 dB

Leq - Equivalent sound level. Steady sound level which, if occurring for a time t, would result in the same amount of sound energy as the time varying sound level over the same time period.

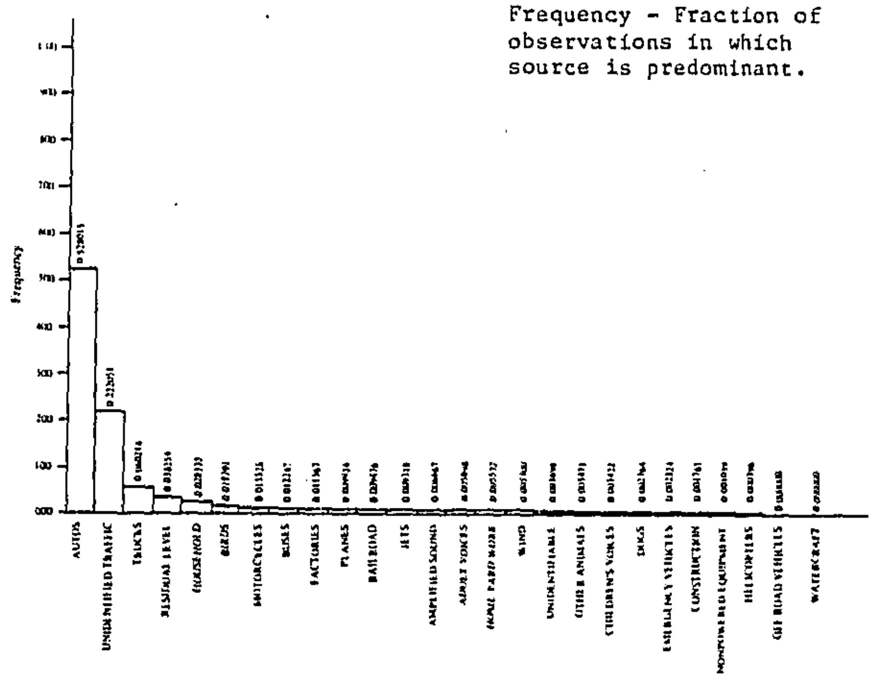
Ldn - Day-night sound level. The equivalent sound level over a 24-hour time period, with a 10-dB penalty added for noise levels occurring between 10 p.m. and 7 a.m.

Patterns of hourly variation are roughly the same for high- and low-traffic-impact areas. Noise levels are lowest at 4 a.m., increase rapidly until 9 a.m., remain fairly constant through 6 p.m., and decrease rapidly after that. If, as EPA noise impact criteria suggest, a 10-dB weighting factor is added to noise levels between the hours of 10 p.m. and 7 a.m., the resulting levels would be higher than the daytime levels, and highest near the beginning and end of the nighttime period.

Roadway traffic is the dominant noise source in both high- and low-traffic-impact areas. The most commonly noted sources in high-traffic areas are autos, unidentified traffic, trucks, and household sounds. Either autos or unidentified traffic is heard 75 percent of the time. In low-traffic areas, the most common sources are unidentified traffic, autos, birds, household sounds, planes, home yard work, trucks, and jets, with autos or unidentified traffic heard 44 percent of the time. Trucks, buses, motorcycles, automobiles, construction, and aircraft are the loudest sources in both high- and low-traffic-impact areas. These results are shown in figure ES-1.

Traffic noise is more prominent at the front of the residential unit, and in the daytime. Most other sources are louder at the front, but are heard more frequently at other sides where there is less traffic noise. Other source levels also appear higher in the daytime, partly as a result of the higher traffic noise levels which the sources must exceed to be identified.

The data were analyzed to determine the effects of traffic impact, urban area size, and population density on day-night sound levels and on source contributions. Traffic impact and population density were found to be significant. The population density effect is most pronounced when its logarithm is used as the independent variable. It was found that the day-night sound



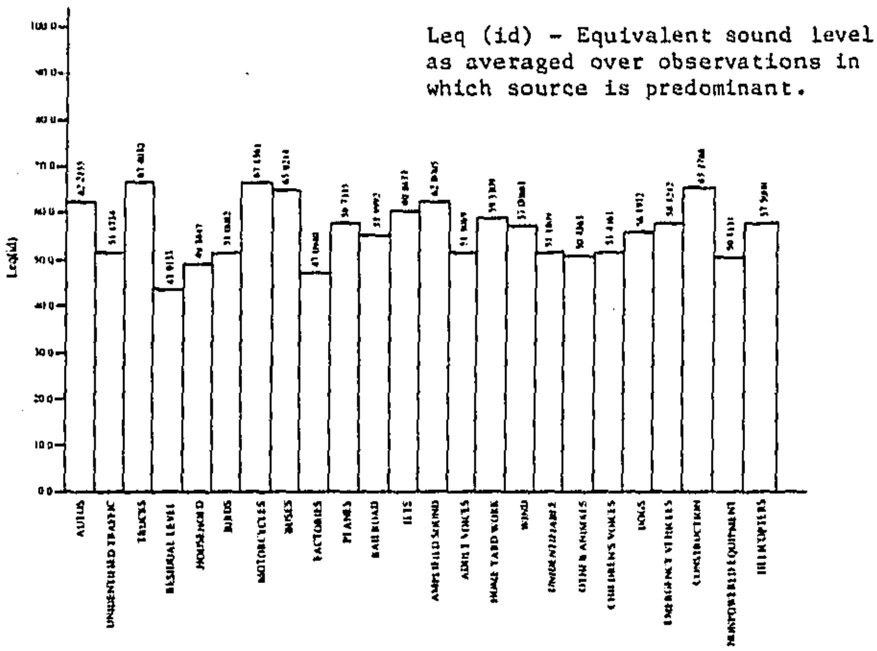


Figure ES-1A. Source Contribution Profile, High-Traffic-Impact Areas

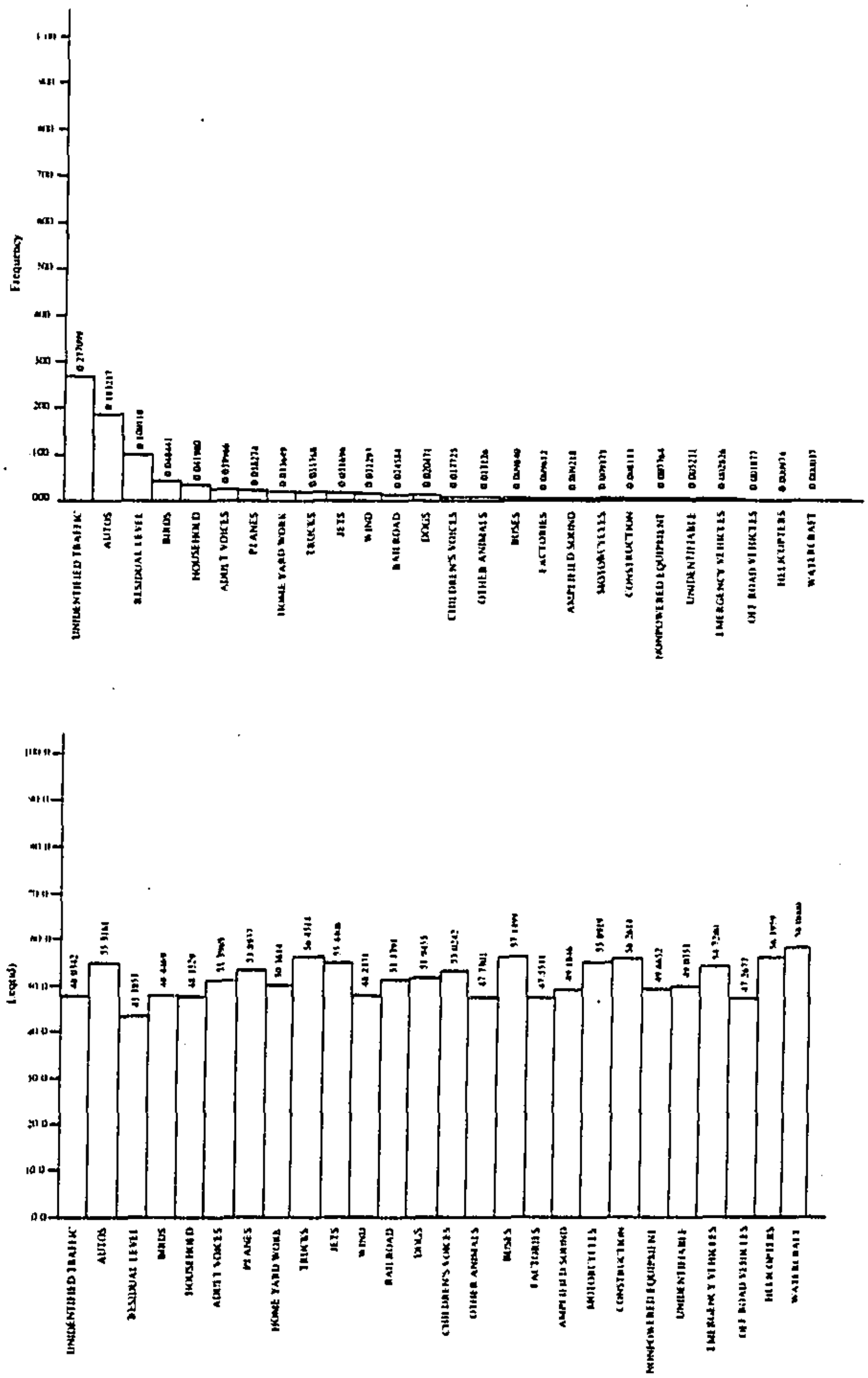


Figure ES-1B. Source Contribution Profile, Low-Traffic-Impact Areas level can be predicted to within a standard error of 3.7 dB by the equation:

$$Ldn = 42.3 + 4.7 \times (\log 10 \text{ UZ density}) + 7.9 \text{ (traffic)}$$

where UZ density is the urban zone population density, and,

traffic = 1 for high traffic impact

= 0 for low traffic impact.

This equation predicts day-night levels in excess of the 55-dB threshold of impact even in low-density, low-traffic-impact areas. It also suggests that the population exposed in excess of 75 dB, the level at which hearing damage may result, is restricted to the high-traffic-impact areas.

The frequency of identification of sources was found to depend mostly on traffic impact, with roadway sources identified more often and other sources less often in high-traffic-impact areas. Population density was also found to be somewhat significant in low-traffic-impact areas, with the frequencies of identification of traffic increasing and those of natural and household sources decreasing with population density.

Traffic impact was found to significantly affect roadway source noise levels. Population density was found to significantly affect all source levels except for those of traffic in high-traffic-impact areas. With this exception, noise levels associated with virtually all sources increase with population density.

In conclusion, residential noise is a problem throughout urban America, and this problem is greatest near major roadways and in areas with high population densities. Among its solutions, the most effective will focus on roadway sources, on the especially high noise levels at the front of residential units, and on the particularly great noise impacts which occur at the beginning and end of the nighttime period. While roadway sources are by far the greatest contributors, other controllable sources become increasingly prominent in higher density areas. Thus, as density increases, so do both noise exposures and the variety of significant causes of them. As noise increases, so do both the magnitude and the complexity of the noise problem.

CHAPTER 1. INTRODUCTION

1-1 BACKGROUND AND PURPOSE

Section 14(d) of the Noise Control Act of 1972, as amended by the Quiet Communities Act of 1978, requires the development and implementation of "a national noise assessment program to identify trends in noise exposure and response, ambient levels, and compliance data, and to determine otherwise the effectiveness of noise abatement actions through the collection of physical, social, and human response data."

In partial fulfillment of this requirement, a national survey of urban residential noise environments has been conducted. The objectives of this survey were:

a. To assess the residential exposure of the urban population of the United States to outdoor noise.

b. To determine the relative contributions of various types of noise sources to this exposure.

c. To assess the influence of various locational factors, such as population, population density, and proximity to roadways, on a and b, above.

The methods and results of this survey, called the National Ambient Noise Survey, are the subject of this report.

1-2 ORGANIZATION

The report is organized so that it may accommodate readers with a variety of technical backgrounds and interests. The main body of the report outlines the objectives and methodology and presents the main results. Supplemental information regarding the methodology and analyses used to obtain the results is presented in the appendixes. The intention is that the main body of the report be accessible and of interest to a wide audience, and that the appendixes provide documentation for those who have more specialized interests in environmental acoustics, noise control, and statistics.

1-3 USING THE REPORT

The National Ambient Noise Survey generated a large body of data concerning urban residential noise environments in the United States. This report attempts to convert this data into information that is useful to those who wish to combat this form of noise pollution.

The information provided will be helpful in addressing two major issues related to noise control policy development. The first issue is that of problem definition. In this context, the report can serve as a basis for predicting noise levels and source contributions in different types of urban residential settings. Equivalently, the report establishes norms for the noise environments in these various settings, against which local survey results can be compared. Such comparison would provide a basis for assessing the relative severity of a noise climate in a particular area.

The report also provides some input regarding the probable effectiveness of various types of noise control strategies in different types of urban settings. In this context, the information provided serves as a basis for first-order estimates of the acoustical impact of the strategies, especially as they relate to control of noise emissions from specific types of sources, or the control of noise levels at specific locations or times of the day. Of course, the acoustical impact of noise control measures represents just one dimension against which their desirability must be assessed; political, attitudinal, and economic assessments are also vital in this process. Nonetheless, noise problems originate with acoustical phenomena, and so it must be with the solutions to these problems.

Finally, a note of caution. The National Ambient Noise Survey represents a first attempt at developing empirically a national profile of residential noise environments. As such, it was a pilot study, and one which was intended more as a basis for further investigation than as an end in itself. The results of the survey must therefore be viewed as tentative, and, one would hope, stimulative of further investigation. The uses of these results are many, but it is important to give due consideration to the limited scope and exploratory character of the study.

CHAPTER 2. SURVEY RATIONALE

2-1 INTRODUCTION

To develop a study responsive to the objectives identified in chapter 1, it was necessary to take into account the criteria that the Environmental Protection Agency (EPA) has adopted for measuring residential noise impact and the limitations on the types and quantity of acoustical measurements which could be performed in the field based upon both technical and resource constraints. This chapter describes how these factors were used to develop a set of information objectives, which in turn served as the basis for developing the survey methodology discussed in chapter 3.

2-2 ASSESSING NOISE EXPOSURE

Noise exposure experienced in the residential environment is but one of many modes of noise exposure to which people are subject in their day-to-day lives.

Such exposure is considered particularly important, however, because people spend more time home than at any other location. The most widespread form of residential noise exposure is that which occurs when noise from exterior sources intrudes upon the interior residential environment. This circumstance results in interference with speech communication, sleep disruption, and other types of interference with household activities. This interference, in combination with various intervening psychological and social factors, can result in annoyance and adverse community reaction.

EPA has determined that the simplest noise metric which correlates well with these effects is the day-night noise level (Ldn). This metric is defined on the basis of a 24-hour day and includes a 10-dB penalty for noise levels between the hours of 10 p.m. and 7 a.m. It is computed using the equation:

$$L_{dn} = 10 \times \log ((15/24 \times 10^{L_d/10}) + (9/24 \times 10^{L_n+10/10}))$$

Ld - Equivalent sound level from 7 a.m. to 10 p.m.
Ln - Equivalent sound level from 10 p.m. to 7 a.m.

It has been found that, as residential Ldn varies between 55 dB and 75 dB, the expected adverse reaction varies from little at 55 dB to a high degree of annoyance at 75 dB, with the proportion of individuals highly annoyed assumed to increase linearly in between. This has led EPA to associate with residential noise exposure a "fractional impact," which estimates the proportion of a population experiencing a high degree of noise-induced annoyance. This impact, called the Noise Impact Index (NII), is given by the equation:

$$NII = \frac{1/20 \sum_{L_{dn}=55}^{75} P(L_{dn})(L_{dn}-55)}{P}$$

P(Ldn) - Population exposed to residential noise level Ldn.
P - Total population.

Although the day-night sound level is a useful descriptor for predicting noise impact, other acoustical factors should also be considered in assessing residential noise impact. Among these are temporal and spatial variation in sound levels around the residential unit.

The scenario of noise from exterior sources impinging upon the interior residential environment suggests that noise levels at locations near the residential unit facade are the most directly related to residential noise impact. In most cases, however, these levels change significantly depending upon which facade (front, rear, or sides) is considered. Although noise levels at the front of the unit are generally considered the most significant, it is expected that any sizable differentials between these levels and those at other facades will have an effect on the overall reaction experienced within the unit. These differentials, therefore, require consideration in assessing residential noise exposure.

The temporal variation of noise levels must also be considered. Noise levels vary over time, whether measured in seconds, hours, days, months, or years. These patterns of variation, when conjoined with human psychological susceptibilities and patterns of activity, represent the actual conditions under which noise impacts arise. Although it may not be possible to develop noise impact criteria which take all of these variations into account, it is desirable to obtain some understanding of these temporal patterns in noise levels. Of particular interest in the context of this survey were the hourly, daily, and instantaneous variations.

The study was therefore designed with the intention that it furnish answers to the following questions:

a. How is the urban population distributed with respect to residential Ldn?

b. What is the typical variation in noise levels between the front, rear, and sides of a residential unit?

c. How do noise levels vary daily, hourly, and instantaneously?

2-3 SOURCE CONTRIBUTIONS

The Noise Impact Index described above is assumed to be source-independent. Therefore, the contribution of a particular type of noise source to residential noise exposure can be estimated in terms of the day-night noise level which results from this type of source. In situations in which a certain type of source is clearly dominant, this day-night level can be equated with the overall day-night level. Unfortunately, many noise environments include noise from several different types of sources, none of which is consistently dominant. In these cases, it is not technically feasible to measure the day-night levels that result from each individual type of source. This necessitates the use of descriptors that are only indirectly related to exposure contributions, but are directly measurable. Two such descriptors are commonly employed in this context. One is the frequency with which a type of source is predominant. The other is the average noise level when a certain type of source is predominant. Both of these descriptors rely upon the judgments of field observers regarding what type of source is predominant at any particular moment.

As in the case of overall noise levels, spatial and temporal variation should also be considered in assessing source contributions.

These considerations implied three information objectives regarding source contributions:

a. How frequently are different types of noise sources predominant in the urban residential noise environment?

b. What are the average noise levels when particular types of sources are predominant?

c. How do source contributions vary temporally and by side of residential unit?

2-4 TYPOLOGY AND FACTOR ANALYSIS

In addition to assessing noise exposure and source contributions for the urban population as a whole, another objective of the survey was to obtain similar information for the different types of urban environments that compose this aggregate. This information was desired in order to enhance the quality of the aggregate information, to allow greater specificity in comparisons with and predictions of local noise environments, and for factor analysis.

To define these objectives further, it was necessary to develop a typology for urban areas that would take into account their most potentially significant characteristics, while at the same time limiting the number of categories so that a reasonable number of measurements could be made in each one. Four parameters were selected to be included in this typology. These parameters, which will be defined more precisely in chapter 3, include metropolitan area size, area population density, distance from major roadways (traffic impact), and location with respect to flight paths around major airports (aircraft impact). These parameters were used because of their significance to noise environments, the ease with which they can be evaluated for a particular area or location, and the availability of estimates of the residential populations of each defined type of urban area. The latter parameter was used to exclude from consideration areas which are heavily impacted by aircraft noise. The three other parameters were used to define a sampling cell structure.

Two information objectives concerning these three parameters were defined:

a. How is residential Ldn affected by urban area size, population density, and proximity to major roadways?

b. How are source contributions affected by these parameters?

2-5 SURVEY EVALUATION

The information needs described in this chapter have two things in common. First, the information required pertains to the urban population at large, as opposed to the particular segments of that population with particular noise exposure problems. Second, the information needs could be met through direct measurement and observation of acoustical phenomena. Together, these two attributes defined the set of information objectives that could be reasonably expected to be met by a study such as the National Ambient Noise Survey.

However, such reasonable expectations in no way imply certainty of success. This was especially true in this case, where a relatively small-scale measurement effort was employed to meet a wide variety of information needs pertaining to a large set of urban locations. Thus, a final objective was to assess the utility of direct measurements in obtaining the desired information. In this respect the survey was not only an investigation of urban noise, but also of the role of noise monitoring in this investigation.

CHAPTER 3. METHODOLOGY

3-1 BASIC APPROACH

The basic approach of the National Ambient Noise Survey was to divide the set of urban residential units in the United States into subsets, called sampling cells, select a random sample of units in each sampling cell, and develop statistically valid profiles of the residential noise environments in each sampling cell based on measurements taken at the selected units.

To determine the set of urban residential units, the 1970 U.S. Census was used. The census compiled a list of 248 "urbanized areas." Each area consists of at least one central city and surrounding closely settled territory. An urban residential unit is defined as one that is located within one of the urbanized areas.

With each residential unit is associated a "noise environment." This is defined as the immediate noise field surrounding the exterior facades of the residential unit. Thus, for the purpose of the study, noise environments are assumed to be individuated by residential unit.

3-2 CATEGORIES OF RESIDENTIAL UNITS

The set of urban residential units is divided into sampling cells on the basis of urban area size, population density, distance from major roadways ("traffic impact"), and location with respect to aircraft flight paths ("aircraft impact"). A category is specified by four indices, each corresponding to a range of values of one of the parameters.

3-2-1 Urban Area Size

The urban area size parameter is defined on the basis of the urbanized area population as determined by the 1970 census. These populations are given in table 20 of the 1970 U.S. Census of population, U.S. Summary. A portion of this table is shown in table 3-1.

Two categories of urban area size are defined. "Large" urbanized areas are those with a population of 2 million or above. All others are classified as "medium-small" urbanized areas.

Referring to table 3-1, the Chattanooga, Tenn. - Ga. urbanized area is seen to fall in the medium-small category, while Chicago, Ill. - Northwestern Indiana is in the large urbanized area category.

3-2-2 Population Density

As depicted in table 3-1, each urbanized area is divided into two or more components. For example, the Chattanooga urbanized area consists of Chattanooga City and outside Chattanooga City, and the Chicago area consists of Chicago, East Chicago, Gary, Hammond, and outside central cities. These components will be called "urban zones."

The population density metric used in the survey is the urban zone population density based on the 1970 census. These densities, based on gross land area, are also given in table 20.

Four categories of population density (persons per square mile) are defined. Densities of 4,500 or over are classified as "high." Densities between 2,500 and 4,499 are "medium-high". Those between 1,500 and 2,499 are "medium-low". Densities below 1,500 are classified as "low."

Table 3-1. Excerpt from U.S. Summary, Table 20

Table 20. **Population and Land Area of Urbanized Areas: 1970 and 1960**—Continued

[For meaning of symbols, see text]

Areas	1970 Population: Number	1970 Population: Percent distribution	1970 Land area in square miles	1970 Population per square mile of land area	1960 Population: Number	1960 Population: Percent distribution	1960 Land area in square miles	1960 Population per square mile of land area	Percent change in population, 1960 to 1970
Champaign-Urbana, Ill.	100,417	100.0	18.3	5,487	78,014	100.0	11.7	6,668	28.7
Inside central cities	89,332	89.0	13.4	6,667	76,877	98.5	10.7	7,185	16.2
Champaign	56,532	56.3	8.3	6,811	49,583	63.6	6.5	7,628	14.0
Urbana	32,800	32.7	5.1	6,431	27,294	35.0	4.2	6,499	20.2
Outside central cities	11,085	11.0	4.9	2,262	1,137	1.5	1.0	1,137	874.9
Charleston, S.C.	228,399	100.0	99.2	2,302	160,113	100.0	31.2	5,132	42.6
Charleston city	66,945	29.3	17.2	3,892	65,925	41.2	5.5	11,986	1.5
Outside central city	161,454	70.7	82.0	1,969	94,188	58.8	25.7	3,665	71.4
Charleston, W. Va.	157,662	100.0	61.8	2,551	169,500	100.0	53.6	3,162	-7.0
Charleston city	71,505	45.4	27.2	2,629	85,796	50.6	26.1	3,287	-16.7
Outside central city	86,157	54.6	34.6	2,490	83,704	49.4	27.5	3,044	2.9
Charlotte, N.C.	279,530	100.0	105.7	2,645	209,551	100.0	72.1	2,906	33.4
Charlotte city	241,178	86.3	76.0	3,173	201,564	96.2	63.0	3,199	19.7
Outside central city	38,352	13.7	29.7	1,291	7,987	3.8	9.1	878	380.2
Chattanooga, Tenn.-Ga.	223,580	100.0	116.7	1,916	205,143	100.0	89.0	2,305	9.0
Chattanooga city	119,082	53.3	52.5	2,268	130,009	63.4	36.6	3,552	-8.4
Outside central city	104,498	46.7	64.2	1,628	75,134	36.6	52.4	1,434	39.1
Chicago, Ill.-Northwestern Ind.	6,714,578	100.0	1,277.2	5,257	[1]5,961,634	100.0	955.7	6,238	12.6
Inside central cities	3,697,144	55.1	301.0	12,283	3,898,091	65.4	296.7	13,138	-5.2
Chicago	3,366,957	50.1	222.6	15,126	3,550,404	59.6	221.7	16,014	-5.2
East Chicago	46,982	0.7	12.3	3,820	57,669	1.0	11.8	4,887	-18.5
Gary	175,415	2.6	42.0	4,177	178,320	3.0	40.5	4,403	-1.6
Hammond	107,790	1.6	24.1	4,473	111,698	1.9	22.7	4,921	-3.5
Outside central cities	3,017,434	44.9	976.2	3,091	[1]2,063,543	34.6	659.0	3,131	46.2
Cincinnati, Ohio-Ky.	1,110,514	100.0	335.1	3,314	993,568	100.0	241.5	4,114	11.8
Cincinnati city	452,524	40.7	78.1	5,794	502,550	50.6	76.5	6,569	-10.0
Outside central city	657,990	59.3	257.0	2,560	491,018	49.4	165.0	2,976	34.0
Cleveland, Ohio	1,959,880	100.0	646.1	3,033	1,783,436	100.0	581.4	3,067	9.9
Cleveland city	750,903	38.3	75.9	9,893	876,050	49.1	75.9	11,542	-14.3
Outside central city	1,208,977	61.7	570.2	2,120	907,386	50.9	505.5	1,795	33.2
Colorado Springs Colo.	204,766	100.0	80.0	2,275	100,220	100.0	28.3	3,541	104.3
Colorado Springs city	135,060	66.0	60.8	2,221	70,194	70.0	15.7	4,471	92.4
Outside central city	69,706	34.0	29.2	2,387	30,026	30.0	12.6	2,383	132.2

Again referring to table 3-1, Chattanooga City is seen to fall in the medium-low-density category. In the Chicago urbanized area, Chicago is in the high-density category, while all other urban zones are in the medium-high category.

3-2-3 Traffic Impact

The traffic impact parameter, which represents the proximity of the residential unit to major roadways, is based upon the Federal Highway Administration's classification scheme for urban roadways. This scheme includes six functional classes: interstates, freeways and expressways other than interstates, principal arterials, minor arterials, collectors, and local streets.

Two categories are defined. Residential units that are within 300 feet of an interstate or urban freeway or within 100 feet of a principal or minor arterial are put in the "high-traffic-impact" category.* All other residential units are in the "low-traffic-impact" category.

These distances are necessarily somewhat arbitrary. The intent is to include in the high-traffic-impact category only those residential units that are chiefly impacted by major roadways. In general, only residential units that face on arterial streets or are less than three houses distant from interstates and freeways fall into the high-traffic-impact category.

3-2-4 Aircraft Impact

To define the aircraft impact categories, day-night sound level contours around airports were used. These contours delineated areas within which specified ranges of day-night noise levels result from aircraft operations. Examples of these contours are shown in figure 3-1.

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*These distances are measured from the center of the nearest lane of the roadway to the center of the residential unit.

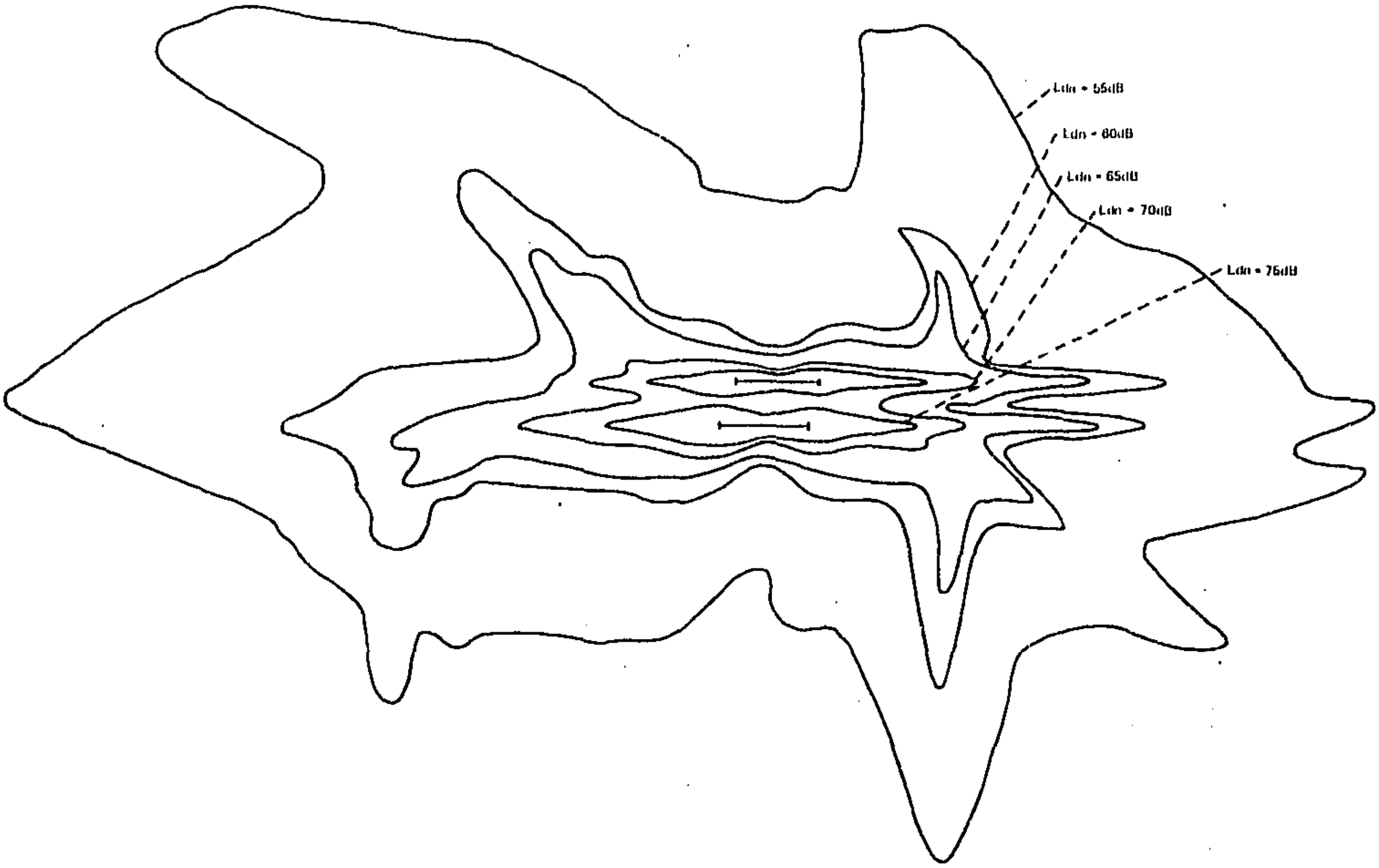

Figure 3-1. Ldn Noise Contours Around a Typical Airport

All residential units located within the Ldn = 65-dB contour are placed in the "high-aircraft-impact" category. All other residential units are in the "low-aircraft-impact" category.

Residential units in the high-aircraft-impact category were not included in the survey. This exclusion was justified by the ability of computer models to predict noise levels in these areas and by the daily variability of these noise environments, resulting from day-to-day changes in aircraft flight paths and air traffic volumes.

3-2-5 Sampling Cells

Table 3-2 summarizes the categories of area size, population density, traffic impact, and aircraft impact described in the previous sections. To define the sampling cells, these four sets of categories are simply combined. Thus, a sampling cell consists of all residential units that fall within the same urban area size, population density, traffic-impact, and aircraft-impact categories.

One important feature of this cell structure is that data are available that permit a calculation of the human population corresponding to each combination of area size, population density, and traffic-impact categories. The calculations rely on 1970 census data and data from the National Roadway Traffic Noise Exposure Model data base. These populations are given in table 3-3 and derived in appendix E.

No data are available that permit the apportionment of these populations into high- and low-aircraft-impact categories. It is estimated that a total of 5.22 million people reside within Ldn = 65-dB contours. Because this represents only about 4 percent of the urban population, little uncertainty is introduced from assuming that this population is distributed among the other categories in the same way as the total population. This assumption was made,

Table 3-2. Summary of Categories Used to Define Sampling Cells

Parameter	Basis for Defining Categories	Number of Categories	Description of Categories
Urban Area Size	Urbanized area population (1970)	2	Large - ≥ 2,000,000 Medium/small - All others
Population Density	Urban zone population density (1970)	4	High - ≥ 4,500/ square mile Medium-high - 3,000-4,500 Medium-low - 1,500-3,000 Low - < 1,500
Traffic Impact	Distance from major roadways	2	High - Within 100 feet of an arterial or 300 feet of an interstate or freeway Low - All others
Aircraft Impact	Ldn contours around airports	2	High - Within Ldn = 65 dB contour Low - All others

Table 3-3. Population (Millions) of Sampling Cells Used in National Ambient Noise Survey (1980 Estimates)

	Large Urban Areas		Medium/Small Urban Areas	
	High	Low	High	Low
High	4.29	25.00	1.47	14.96
Medium-High	3.82	19.49	2.20	19.92
Medium-Low	0	0	3.07	31.7
Low	0	0	0.53	5.78

and the populations given in table 3-3 were assumed in all subsequent calculations. The survey may thus be conceptualized as a survey of the total urban population, but one that does not consider the increment of noise that results from a residential unit being located within an Ldn = 65-dB contour.

The total number of sampling cells defined by the four categories of urban area size, urban zone population density, traffic impact, and aircraft impact is 32. Excluding the high-aircraft-impact cells reduces this number to 16. Of these, four have zero population. This leaves a total of 12 sampling cells to be included in the survey.

3-3 SITE SELECTION

Each of the sampling cells included in the survey represents a subpopulation of urban residential units. Units in each subpopulation were then randomly selected to be used as measurement sites.

The selection process involved five steps. First, the sizes of the samples desired from each sampling cell were determined. Second, urbanized areas were randomly selected. Third, census tracts within each selected urbanized area were randomly selected. Fourth, blocks were randomly selected from within each census tract. Finally, residential units, either high- or low-traffic impact as required, were selected from each selected block. A detailed description of the procedures followed in determining sample sizes and in making these random selections is described in appendix A.

A profile of the sites obtained in the survey is given in table 3-4. A complete listing of the sites is given in appendix F.

Table 3-4. Site Quotas and Sites Obtained for Each Sampling Cell

Urban Area Size	Urban Zone Density	Traffic Impact	1980 Quota	1980 Obtained	1981 Quota	1981 Obtained	Total Quota	Total Obtained	Average Urban Area Population	Average Urban Zone Population Density
Large	High	High	4	4	1	1	5	5	4,844,195	12,524
Large	High	Low	4	4	16	15	20	19	6,678,032	15,773
Large	Medium-High	High	4	4	1	0	5	4	5,049,977	3,786
Large	Medium-High	Low	4	4	11	7	15	11	8,938,089	3,557
Medium-Small	High	High	4	4	1	1	5	5	585,593	8,317
Medium-Small	High	Low	4	4	11	9	15	13	765,491	7,279
Medium-Small	Medium-High	High	4	3	1	1	5	4	184,195	4,111
Medium-Small	Medium-High	Low	4	3	21	18	25	21	588,187	3,610
Medium-Small	Medium-Low	High	4	3	1	1	5	4	477,083	1,964
Medium-Small	Medium-Low	Low	4	4	26	22	30	26	739,398	2,327
Medium-Small	Low	High	4	3	1	1	5	4	187,740	1,122
Medium-Small	Low	Low	4	3	6	5	10	8	208,261	1,248
Total			48	43	97	81	145	124		

3-4 MEASUREMENT PROTOCOL

3-4-1 Elements of the Protocol

Two types of sound-level measurements were performed at each selected residential unit. Continuous sound-level measurements employing an automated noise-level recorder equipment were performed at the front of each selected unit. Manual sound-level measurements and source identifications, employing a technique called microsampling, were made at accessible sides of each selected unit.

3-4-2 Continuous Measurements

The purposes of the continuous measurements were (1) to accurately measure the Ldn and (2) to provide a detailed time history of sound levels over a 24-hour or longer period at one location near the residential unit. This location was the architectural front of the residential unit and was further specified by rules that took into account such factors as driveway location, window location, and security. The intent of these rules was to obtain a location that represented as closely as possible the external-source-generated noise field at the front side of the unit.

The continuous measurements were generally conducted for a 24-hour period. At a few sites, 5-day continuous measurements were performed to assess daily variation in sound levels.

A discussion of the equipment and analytical procedures used in continuous monitoring is provided in appendix C.

3-4-3 Microsamples

Microsamples were collected to assess source contributions and differentials in noise levels between the front and other sides of the residential unit.

Microsamples consisted of 120 sound-level measurements, employing a Type 2 or better sound-level meter set to "slow" response, and source identifications taken over a 30-minute time period. The microsamples were usually gathered in sets of two, one at the unit near the continuous-measurement location and one at another side. Whenever possible, three such sets were obtained at each site, one each in the daytime, evening, and nighttime periods.* The exact locations at which these measurements were taken depended upon window placement and other architectural factors. As in the case of the continuous measurement, the objective was to accurately represent the external-source-generated noise field at the given side of the unit.

The sound-level measurements were taken every 15 seconds. At the time of each measurement, the type of noise source judged to be predominant was also recorded. Table 3-5 shows the list of source types used in the survey.

3-5 ANALYTICAL PROCEDURES

3-5-1 Data Reduction

The continuous noise-level data were encoded on digital cassette tapes. These tapes were analyzed using a digital translator and computer. The microsample data were keypunched and computer reduced. The reduced data were assembled into a set of Statistical Analysis System data sets for further analysis.

3-5-2 Data Analysis

The data were analyzed to develop information relevant to the objectives discussed in chapter 2. A discussion of some of the more important analytical procedures used is included in appendix D. The results of this analysis are presented in chapter 4.

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*Daytime is 0700-1900; evening is 1900-2200; nighttime is 2200-0700.

Table 3-5. Source Codes Used in Microsamples

A	Auto
B	Bus
C	Construction Equip. (not Y or S)
D	Dog
E	Emergency Vehicle
F	Factory Equip.
G	Unamplified Adult Voice
H	Helicopter
I	Person Using Nonpowered Equip. (not Y or S)
J	Jet
K	Unamplified Child Voice
L	Amplified Sound (not E)
M	Motorcycle
N	Other Animal (not D or O)
O	Bird
P	Prop. Plane
Q	Wind
R	Railroad
S	Household (not G, Y, or K)
T	Truck
U	Unidentified Road Traffic
V	Off-Road Vehicle
W	Water Vehicle
X	Unidentifiable Source
Y	Home Yard Work (not G or K)
Z	Residual Level

CHAPTER 4. RESULTS

4-1 INTRODUCTION

In this chapter, the results of the survey are described. They are presented as answers to the questions posed in chapter 2. The answers presented are based solely upon the data obtained in the survey. Therefore they should be viewed cautiously: 124 sites are being used to represent a population many orders of magnitude greater.

With each answer are included a few remarks regarding its policy implications. These remarks are far from exhaustive, but are intended to illustrate the connections which exist between the information presented and noise control policy development. It is expected that other such connections will be made by the interested reader in light of the local situation which he faces.

The emphasis in this chapter is on presenting information, not a detailed account of how this information was derived from the measurement results. Such an account may be of value to some readers, and is included, along with an error analysis, in appendix D.

It must be emphasized that these results apply to the urban population not residing within Ldn = 65 dB contours around airports. Equivalently, the results may be considered to apply to the entire urban population, but without including the increment of noise which results from living within that contour.

4-2 DISTRIBUTION OF THE URBAN POPULATION OVER Ldn.

Figure 4-1 shows two versions of the distribution. The bars show the "raw" distribution, in which the results of the individual measurements were simply weighted according to the populations of the sampling cells. The curve is the normal curve derived from the individual measurements. The mean Ldn value is 60.4 dB, and the standard deviation is 4.8 dB.

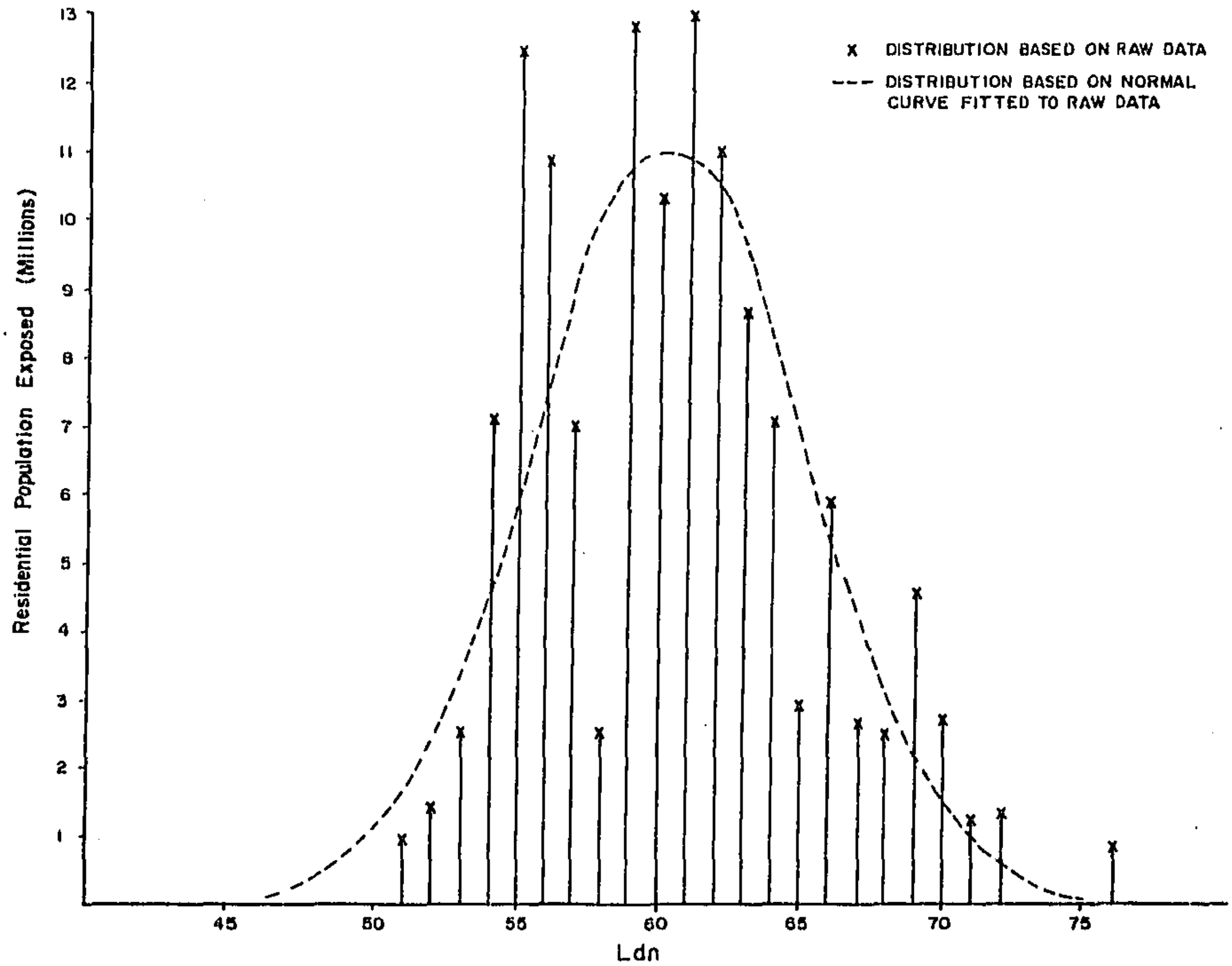

Figure 4-1. Distribution of Urban Population Over Ldn

The irregularity of the raw distribution reflects the small number of data points upon which it is based. The normal curve smooths out the irregularities, and is therefore the preferred approximation of the true distribution.

Table 4-1 shows the percentage of the urban population exposed to residential Ldn over 55, 60, 65, 70, and 75 dB respectively. Earlier EPA estimates, as based on the 100-site study*, are also included.

Table 4-1. Populations Exposed to Critical Values of Ldn
(Percent of Urban Population)

	National Ambient Noise Survey	100-Site Study
Ldn > 55 dB	87%	70%
Ldn > 60 dB	53%	44%
Ldn > 65 dB	17%	18%
Ldn > 70 dB	2%	5%
Ldn > 75 dB	<1%	1%

These estimates indicate that the vast majority of the urban population is exposed to residential noise sufficient to create some adverse impact, but that only a tiny fraction experience the full impact associated with Ldn over 75 dB. Eighty-seven percent of the urban population are sufficiently exposed to experience some benefit from a reduction in noise levels.

The Noise Impact Index, defined in chapter 2, can be computed from these results, and is found to be .28. Thus, based on EPA criteria, 28 percent of the urban population are expected to be highly annoyed as a result of noise in the residential environment.

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*The 100-site study is the previous nationwide study of urban residential noise exposure sponsored by EPA. The study established a relation between Ldn and census tract population density. This relation, in combination with the distribution of the urban population over census tract density, was used to develop the cited estimates.

These results consider noise levels at the front of residential units only. The next section discusses the differentials between these levels and those at other sides.

4-3 VARIATION IN NOISE LEVELS BY SIDE OF RESIDENTIAL UNIT.

Table 4-2 shows the average differentials between noise levels at the front and those at the rear and sides. The information is presented for both high and low traffic areas.

Table 4-2. Differentials in Noise Levels by Side

Traffic Impact	Leq(Front)-Leq(Side)	Leq(Front)-Leq(Rear)
High	4 dB	9 dB
Low	3 dB	4 dB

These differentials result primarily from screening effects and the generally greater distances between roadways and the rear and side locations. They therefore reflect the predominance of roadway traffic in the noise environment in low aircraft impact areas. Whether and how these differentials affect noise impact are interesting and important questions yet to be answered.

These results nonetheless have useful implications for the design and retrofitting of urban housing. Housing layouts which locate the most noise-sensitive areas, such as bedrooms, in the rear will afford such areas maximal protection from exterior noise. Noiseproofing measures, such as double glazing of windows, will realize their greatest benefits when applied to the front of residential units. These considerations are especially important in high traffic impact areas.

4-4 DAILY, HOURLY, AND INSTANTANEOUS VARIATION IN NOISE LEVELS

4-4-1 Daily Variation

Table 4-3 shows the average day-by-day variation in Ldn by day of the week. It is based on the results of the eight sites which were monitored for 5 days continuously.

Table 4-3. Average Ldn by Day of Week

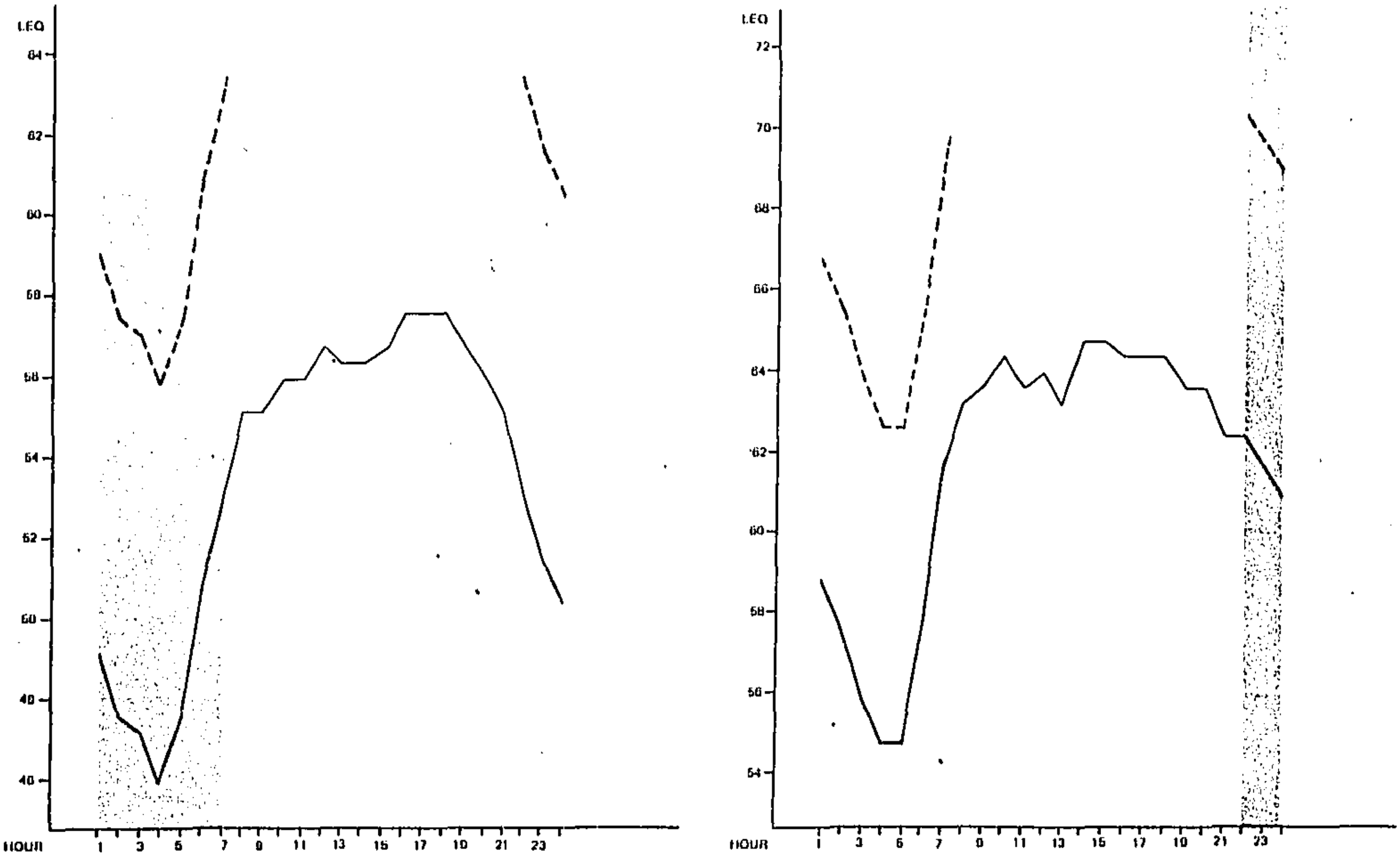
Day	M	T	W	TH	F	S	S
Ldn (dB)	59	59	60	61	61	59	60

The small variations obtained indicate that the day of the week does not significantly affect the Ldn. This conclusion is especially surprising in the case of weekend days, when traffic patterns are significantly different from those on weekdays.

The standard deviation in Ldn for the eight 5-day sites ranged from 1.0 to 2.9 dB, with an average of 2.0 dB. This means that one day of monitoring is usually sufficient to obtain a reliable estimate of the Ldn in low aircraft impact areas.

4-4-2 Hourly Variation

Figure 4-2 shows the variation in hourly Leq values over a 24-hour period for high- and low-traffic-impact areas. The patterns of variation are seen to be remarkably similar in both types of areas, especially during the evening and nighttime hours. Starting at midnight, the levels decrease steadily until about 4 a.m., and increase rapidly between 4 a.m. and 7 a.m. The levels begin to decrease steadily after 6 p.m. During the hours between 7 a.m. and 6 p.m., noise levels remain fairly constant in high-traffic-impact areas, while increasing slightly in low-traffic-impact areas.



High-Traffic Impact   Low-Traffic Impact

Figure 4-2. Average Hourly Leq Values, by Traffic Impact (Dashed line includes 10-dB penalty for nighttime levels.).

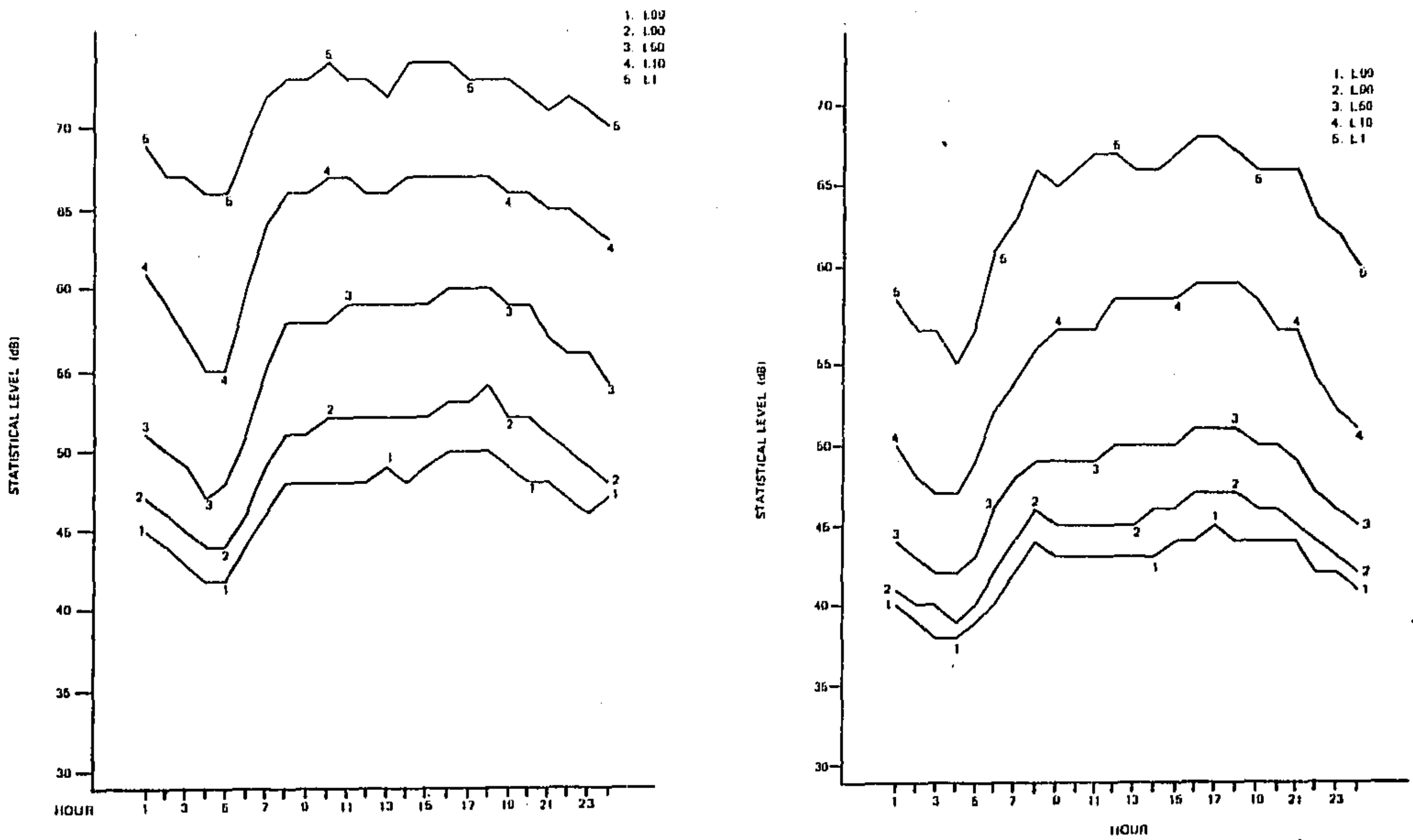
The dashed lines in figure 4-2 indicate Leq values adjusted to reflect the 10-dB weighting factor for noise levels during the evening and nighttime hours used in the calculation of Ldn. When this factor is considered, noise during the nighttime appears to have a substantially greater impact than noise during the daytime, with by far the greatest impacts occurring at the beginning and end of the nighttime hours.

4-4-3 Instantaneous Variation

Instantaneous variation is best described by statistical levels. These descriptors indicate what noise level is exceeded for a given percentage of the time. L1, for example, is the level exceeded 1 percent of the time, and thus describes peak and near-peak levels. L99 is the level exceeded 99 percent of the time, thus defining the "noise floor" of the environment.

Figure 4-3 shows the variation in the statistical levels L99, L90, L50, L10, and L1 over a 24-hour period for high- and low-traffic-impact areas. Instantaneous noise levels are seen to vary more greatly in the daytime and in high-traffic-impact areas. Although all five statistical levels follow the same basic pattern of variation, this pattern is most pronounced in the L1 and L10 levels. The variation in these upper statistical levels is the primary source of the hourly Leq variation described in paragraph 4-4-2.

Of particular interest is the increment between L1 and L10. This increment represents the noise levels resulting from the loudest noise sources. As such it would be most affected by an abatement program targeted at such sources. A plausible goal of such a program would be to reduce all noise levels above the pre-program L10 to levels at or below this value.



High-Traffic-Impact Areas

Low-Traffic-Impact Areas

Figure 4-3. Average Hourly Statistical Levels, by Traffic Impact

Figure 4-4 shows the hourly decreases in Leq that would result if this goal were to be achieved, based on the statistical levels shown in figures 4-3A and 4-3B.* In low-traffic areas, these decreases are generally about 3 dB, with a substantial decrease for the late night hours and some increase for rush hours. The expected decreases are generally about 2 dB in high-traffic areas, but substantially greater during the late night and rush hours.

These observations suggest that a noise abatement program targeted at the noisiest 10 percent of sources would decrease noise levels in low- traffic-impact areas by about 3 dB, which in most cases would result in an Ldn at or below 55 dB, the assumed threshold of impact in the EPA criteria. Such a decrease would also be equivalent to reducing traffic volumes by 50 percent. In high-traffic-impact areas, a somewhat smaller overall decrease would result. However, an abatement program targeting noise levels in the late night hours (perhaps employing curfews) would be especially effective in such areas.

4-5 FREQUENCY OF PREDOMINANCE AND AVERAGE NOISE LEVELS OF SOURCES

Source contributions are described by means of two descriptors, called frequency and Leq (id). Frequency is the proportion of time in which the source was identified as predominant. Leq (id) is the equivalent sound level as averaged over the instances in which the source was so identified. Figures 4-5A and 4-5B show these values for high- and low-traffic areas, based on micro-samples taken at the front measurement site only.

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*The average noise level during the noisiest 10 percent of the time is assumed to be:

$$10 \times \text{Log } 10((10^{L1/10} + 10^{L10/10})/2)$$

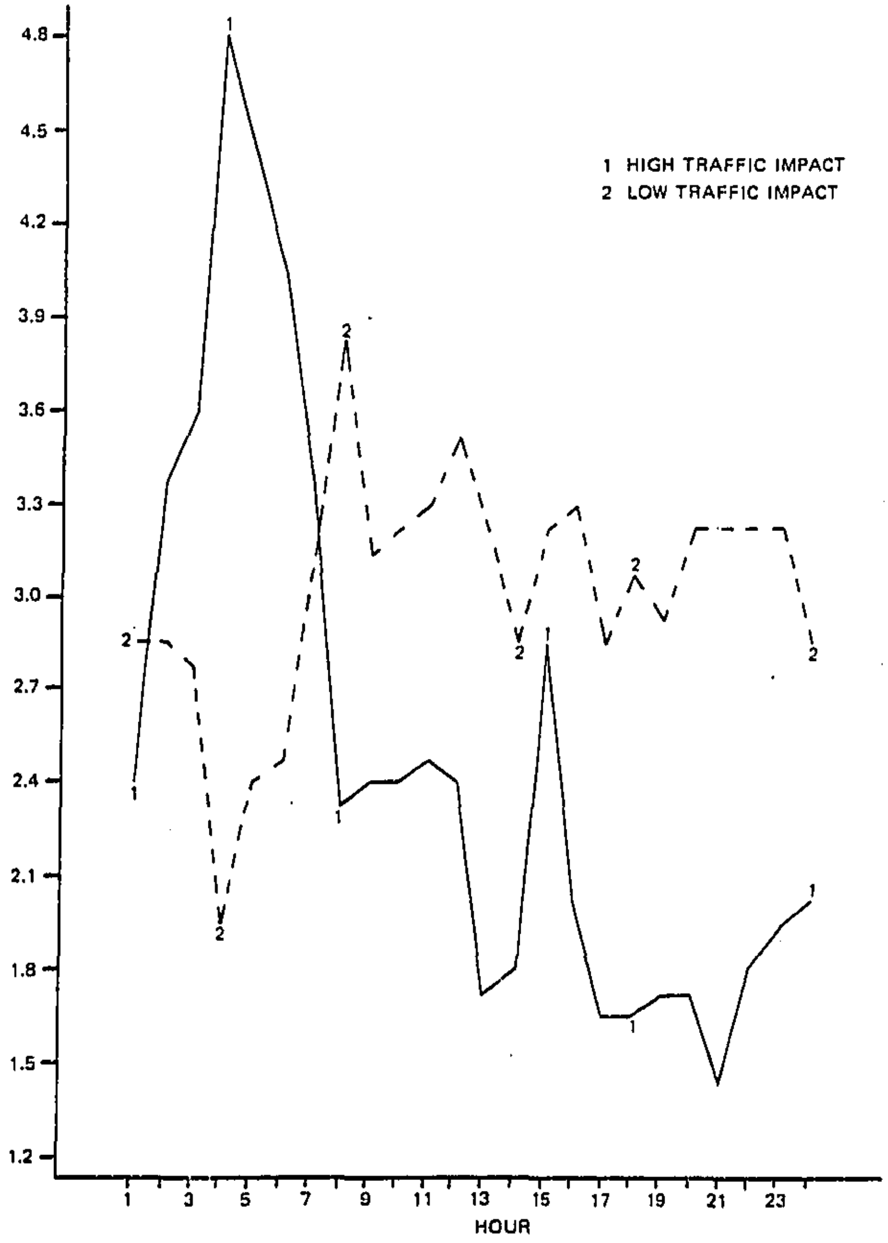
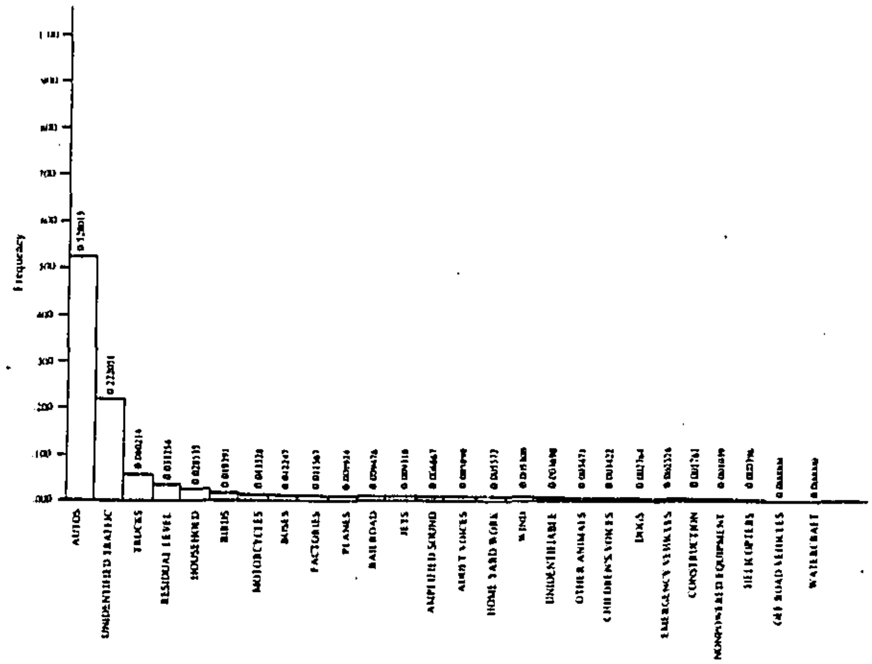


Figure 4-4. Projected Hourly Decreases in Leq Resulting From Achievement of Hypothetical Goal for Noise Control Program



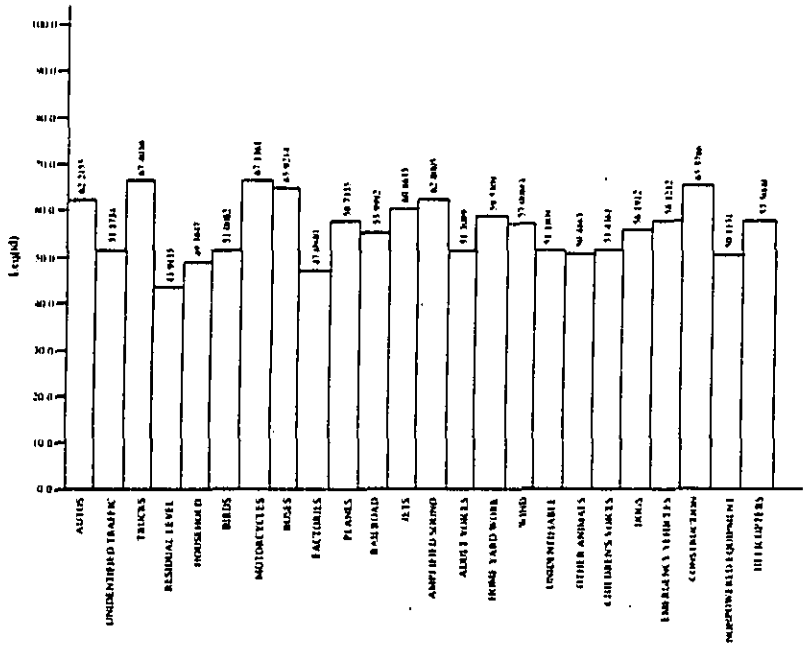
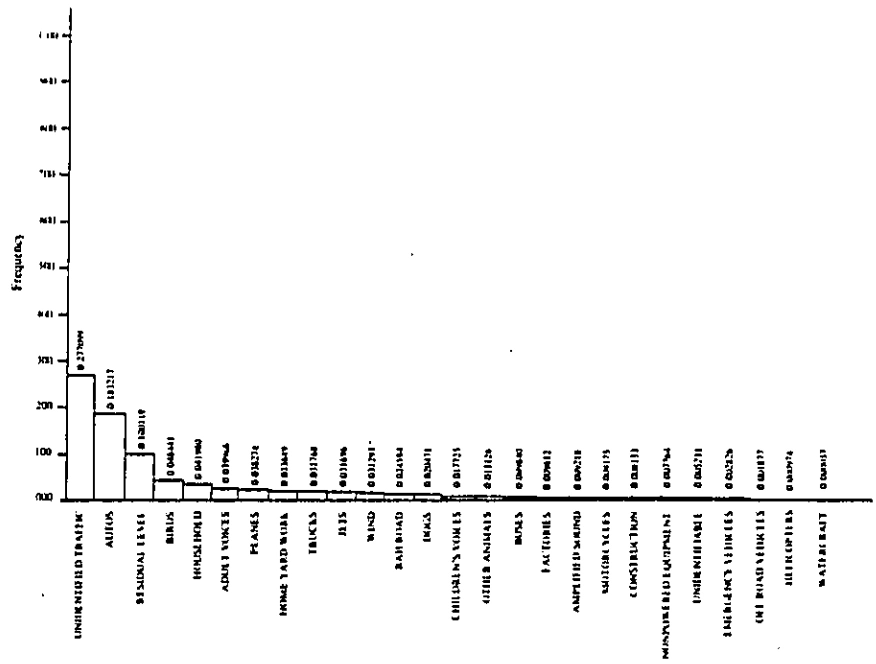


Figure 4-5A. Source Contribution Profile, High-Traffic-Impact Areas



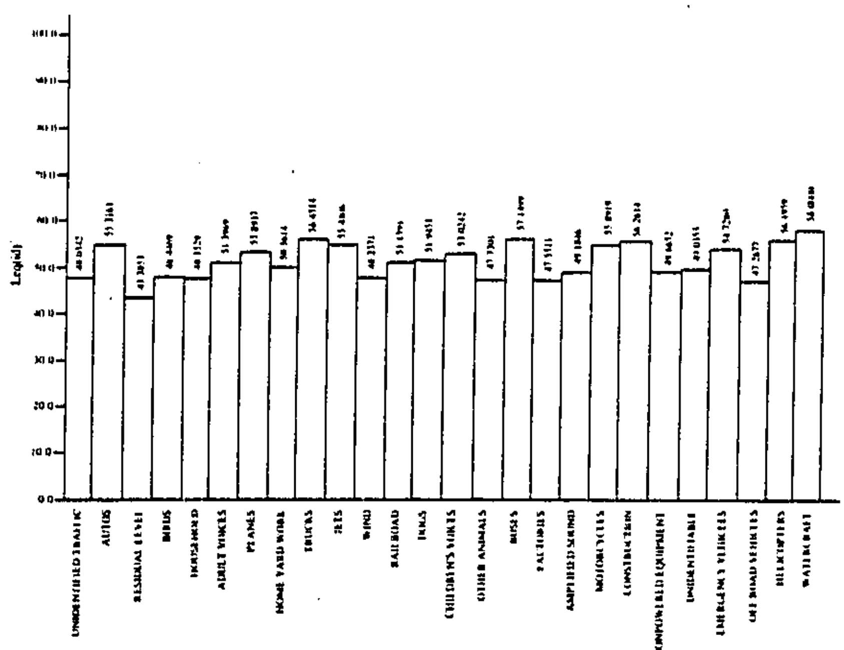


Figure 4-5B. Source Contribution Profile, Low-Traffic-Impact Areas

Unidentified traffic and automobiles are by far the most frequently mentioned sources. Other frequently identified sources are trucks and household sounds in high-traffic areas, and birds, household sounds, voices, aircraft, home yard work, and trucks in low-traffic areas. Residual sound, that which is heard when no particular source is sufficiently loud to be identified, is identified about 3 percent of the time in high-traffic-impact areas and 10 percent of the time in low-traffic-impact areas.

The loudest sources in both traffic impact areas are autos, buses, trucks, motorcycles, aircraft, and construction, all with Leq (id) values over 65 dB in high-traffic impact areas and over 55 dB in low-traffic-impact areas. The sources are the usual targets of noise control programs. Another frequent target which is not among this group is dogs, with Leq (id) values of 56 dB in high-traffic-impact areas and 52 dB in low-traffic-impact areas. This suggests that dog-barking is a noise problem primarily as a result of its expressive content.

Leq (id) values are consistently higher in high-traffic-impact areas. This indicates a more "competitive" noise environment, in which the higher traffic-noise levels must be exceeded by another source in order for that source to be identified. This creates the illusion that even sources unrelated to traffic (birds, for example) are louder in such areas.

4-6 VARIATION OF SOURCE CONTRIBUTIONS BY SIDE OF RESIDENTIAL UNIT

Six sources were selected for analysis of locational and temporal variation of frequency and Leq (id). Three of the sources, autos, trucks, and motorcycles, are roadway traffic sources frequently targeted in noise control programs. Two sources, construction and dogs, are non-transportation sources which are also targeted in many programs. The other source, birds, was selected because of the commonly made association between bird sounds and a pollution-free sound environment.

Figures 4-6A through 4-6F show the frequencies of identification and Leg (id) values of these sources by side for high- and low-traffic-impact areas. They are based on data taken in the daytime hours. The roadway traffic sources are clearly most prominent at the front, with this tendency most strongly pronounced in the high-traffic-impact areas. Construction and dogs are more frequently identified at the rear and sides, although the associated noise levels are higher when they are heard at the front. This reflects the higher competing levels which these sources must exceed in order to be heard at the front. These effects are again more pronounced in high-traffic-impact areas. Birds follow the same basic pattern as dogs and construction with regard to frequency, with little locational variation in Leq (id) values. These observations suggest that noise control programs oriented toward roadway traffic will have their greatest impact on noise levels at the front of residential units. Non-roadway traffic oriented measures will have a more uniform, though smaller, impact.

4-7 TEMPORAL VARIATION IN SOURCE CONTRIBUTIONS

Figures 4-7A through 4-7F show the frequencies of identification and Leq (id) sources of the six sources identified in paragraph 4-6 by time of day, based on data taken at the front only. Daytime refers to hours between 7 a.m. and 7 p.m. Evening refers to the time between 7 p.m. and 10 p.m. Nighttime includes the period between 10 p.m. and 7 a.m.

The roadway traffic sources are predictably less prominent in the nighttime than in the daytime, both in terms of frequency and of Leq (id). In the evening period, autos and motorcycles are as prominent as in the daytime, while trucks are much less prominent. Noise levels associated with roadway vehicles are consistently lower in the nighttime.

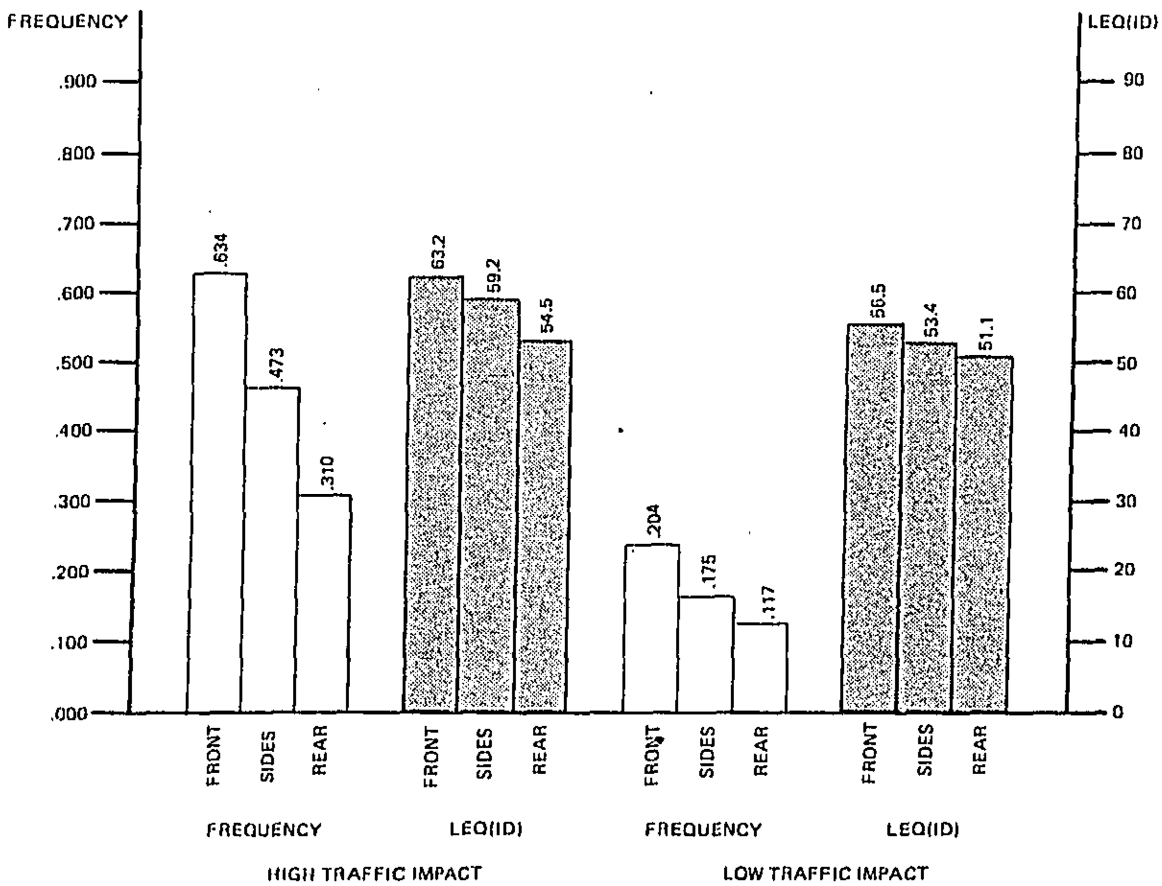


Figure 4-6A. Variations in Automobile Contributions, by Side of Unit

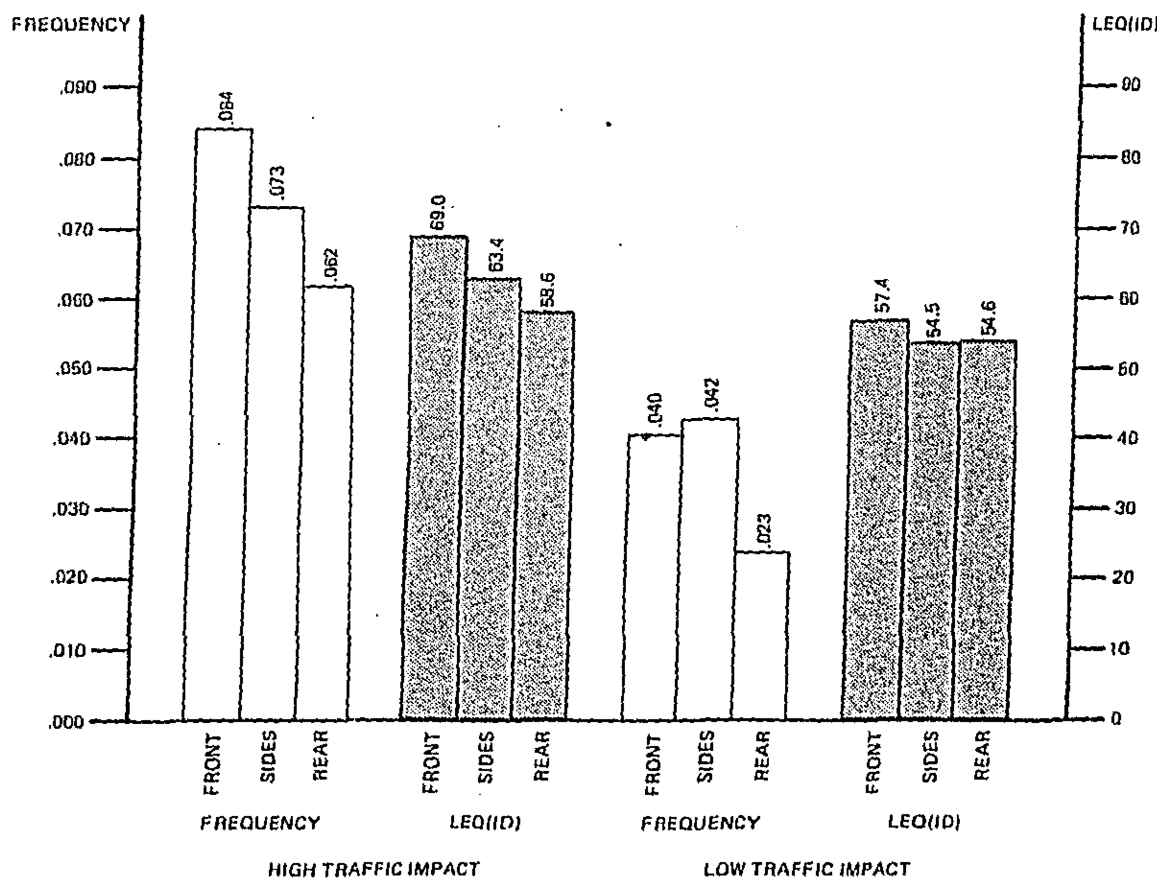


Figure 4-68. Variations in Truck Contributions, by Side of Unit

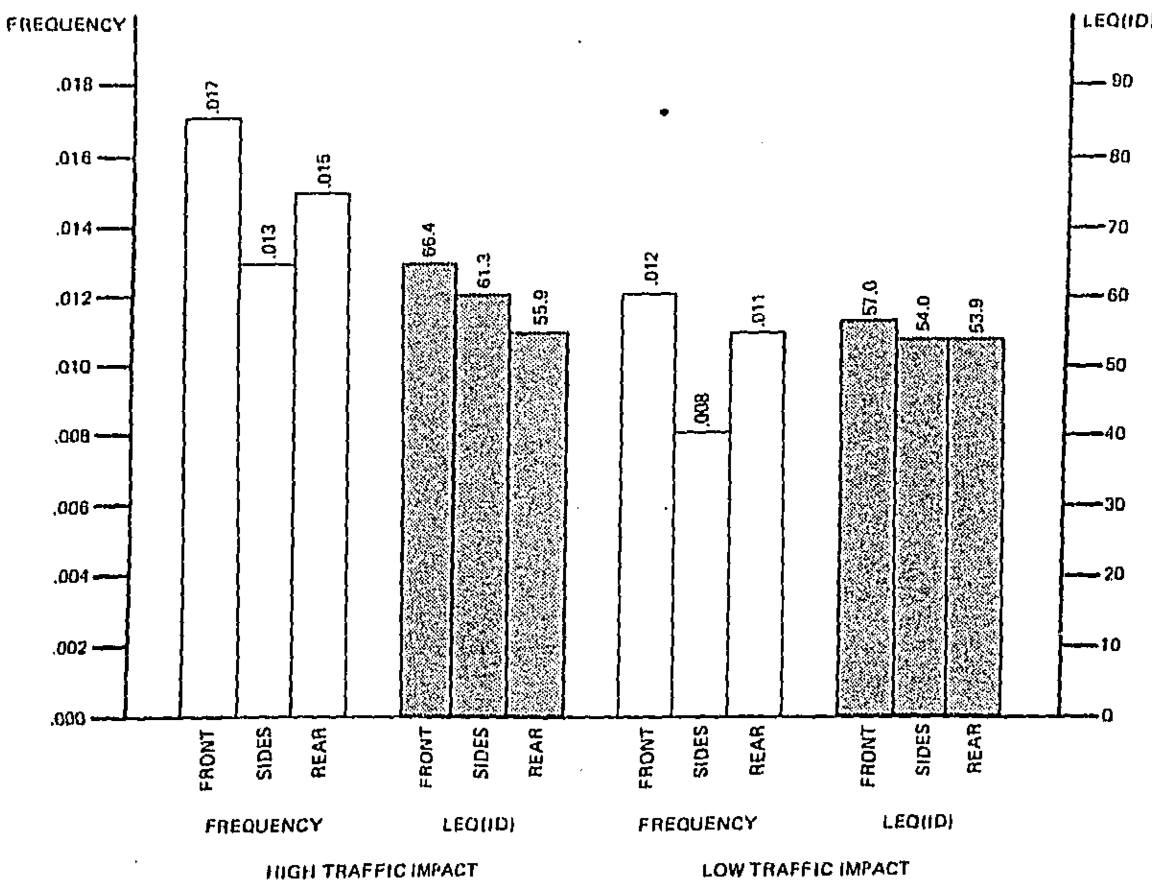


Figure 4-6C. Variations in Motorcycle Contributions, by Side of Unit

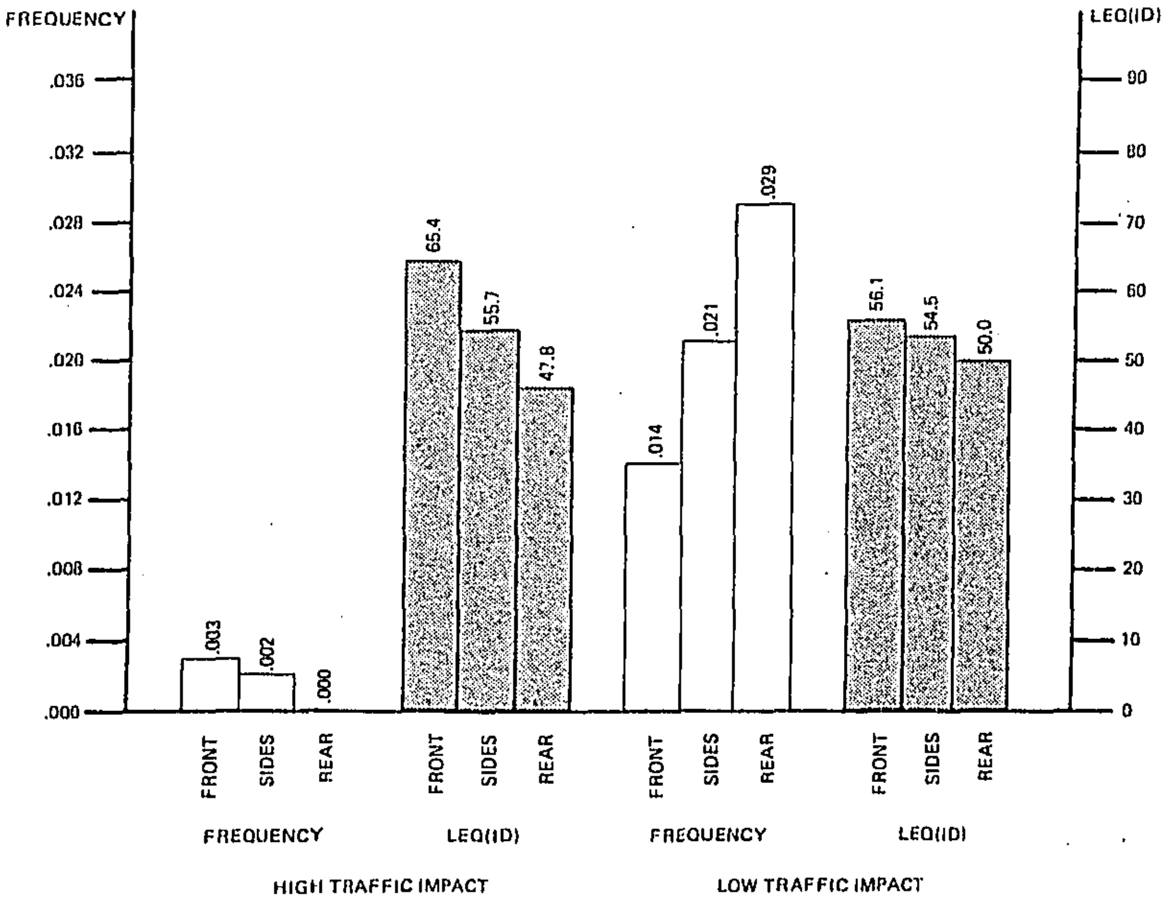


Figure 4-6D. Variations in Construction Contributions, by Side of Unit

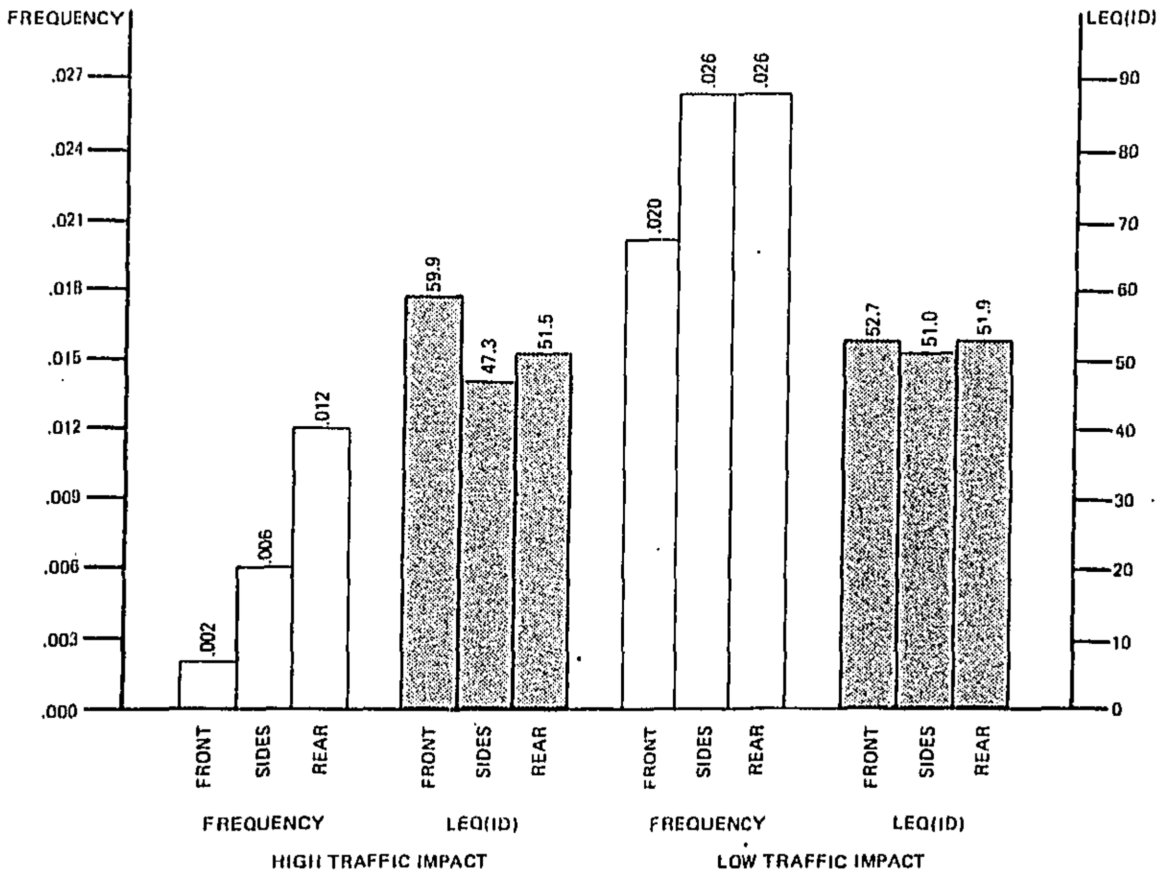


Figure 4-6E. Variations in Dog Contributions, by Side of Unit

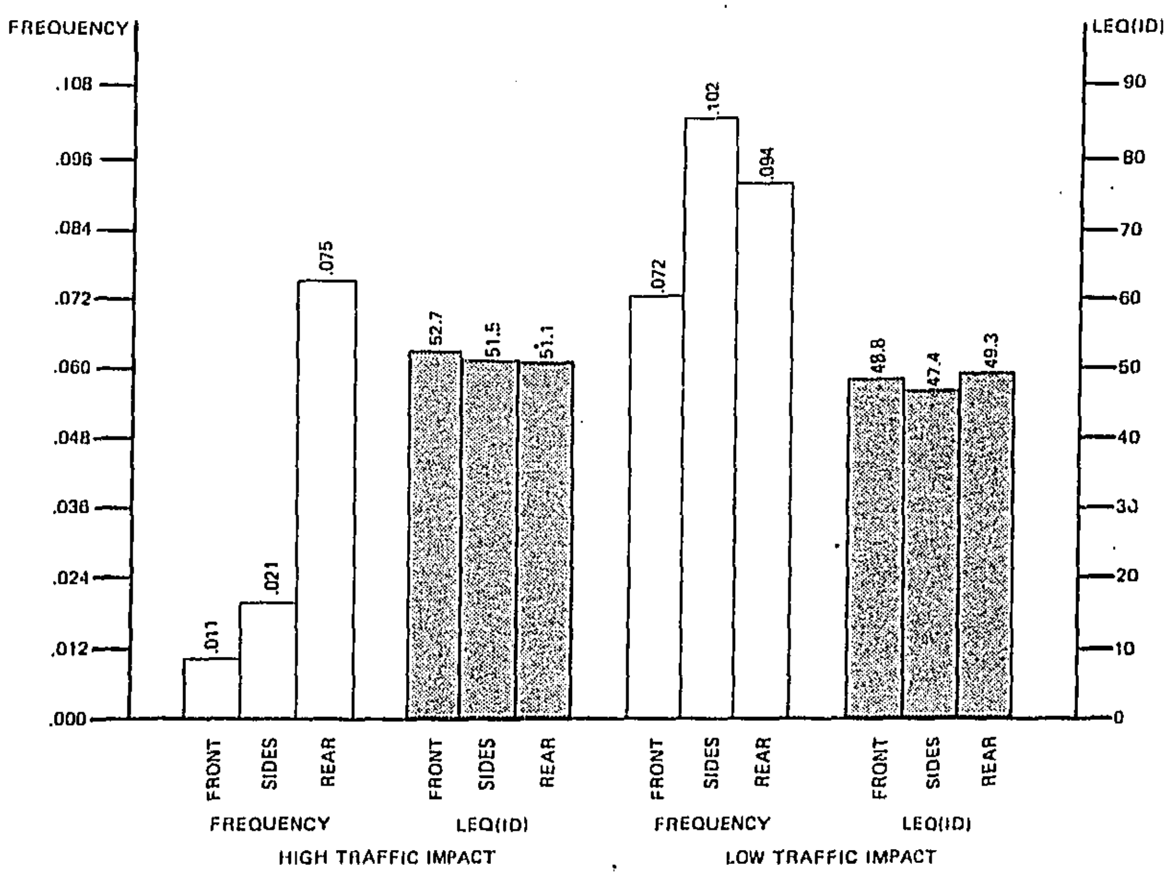


Figure 4-6F. Variations in Bird Contributions, by Side of Unit

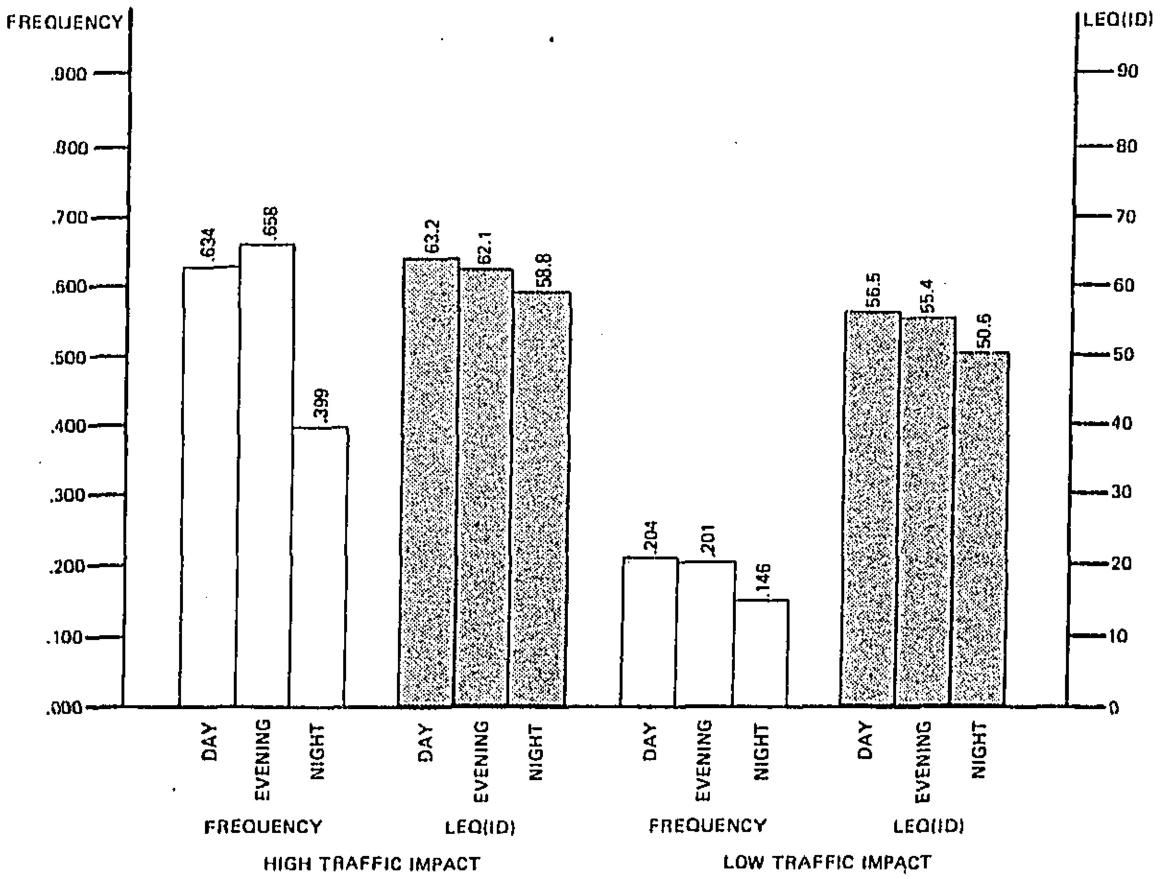


Figure 4-7A. Variations in Automobile Contributions, by Time of Day

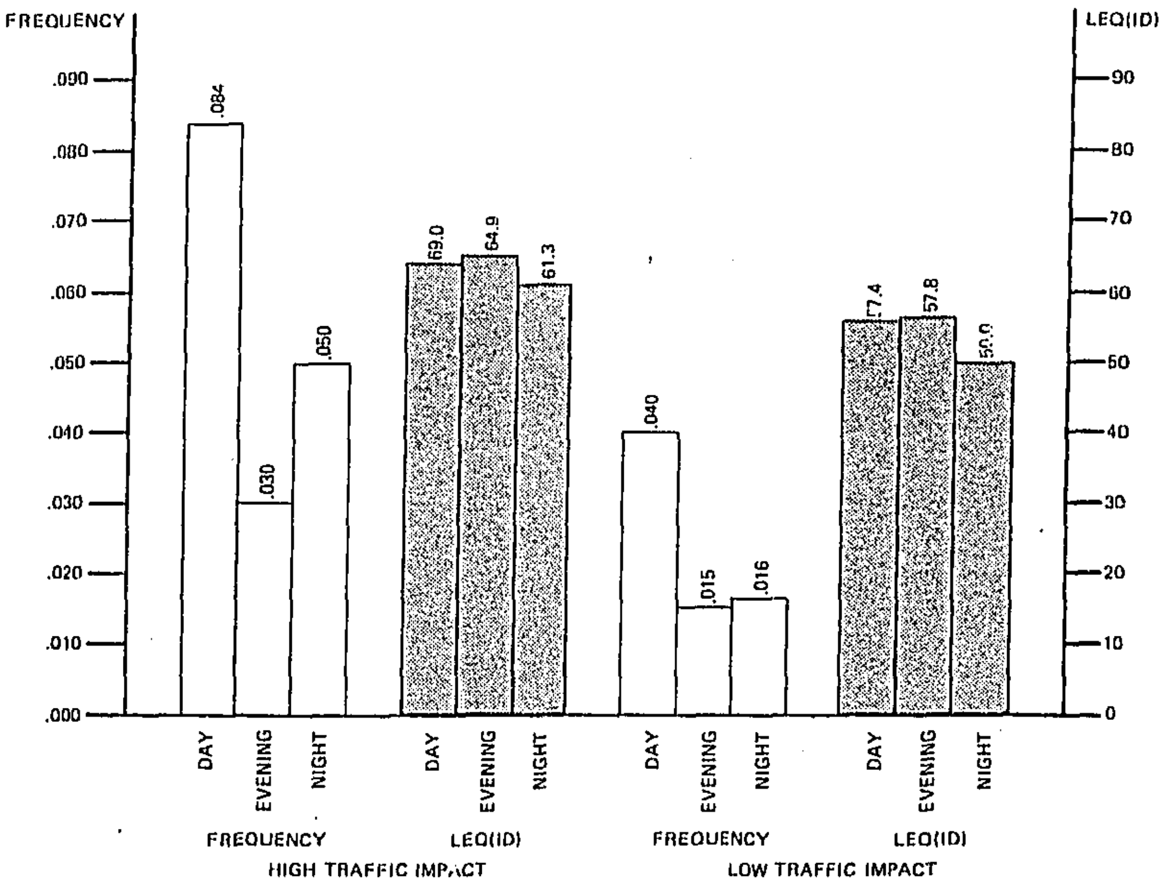


Figure 4-7B. Variations in Truck Contributions, by Time of Day

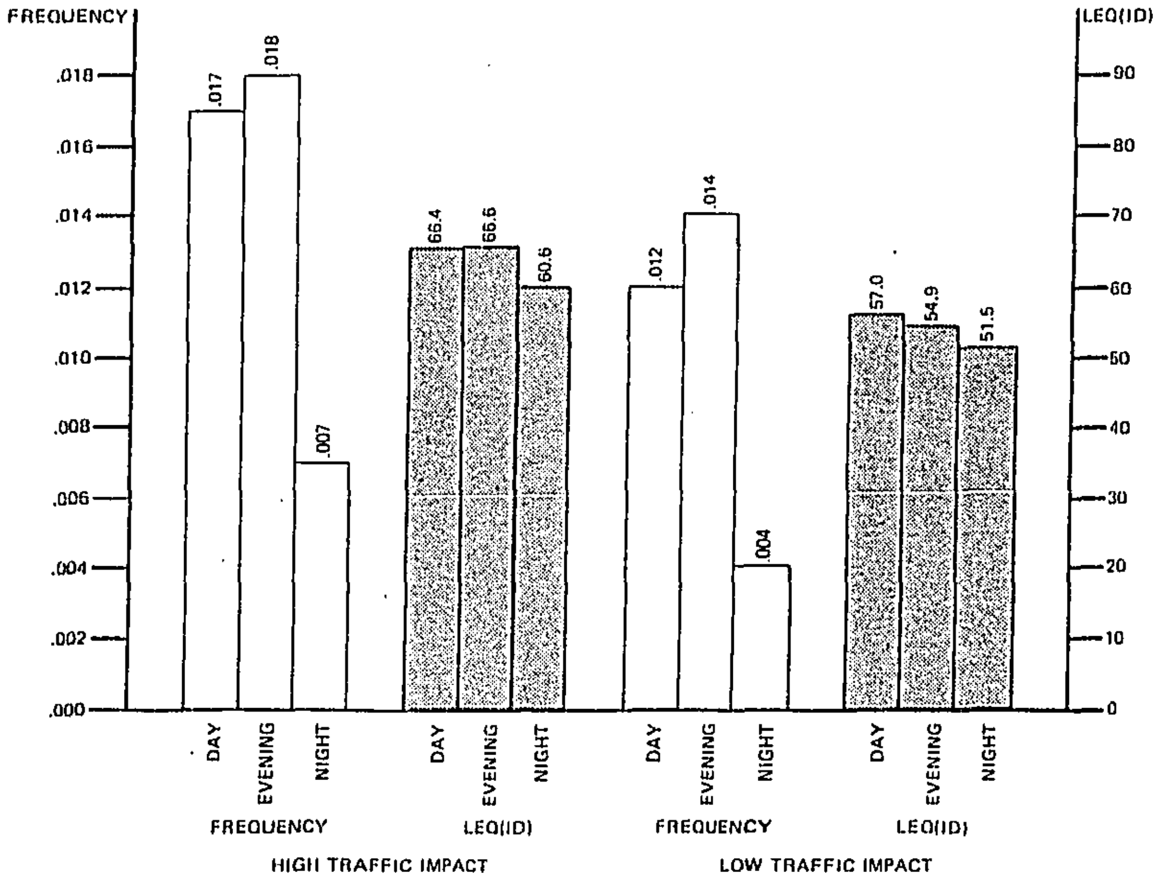


Figure 4-7C. Variations in Motorcycle Contributions, by Time of Day

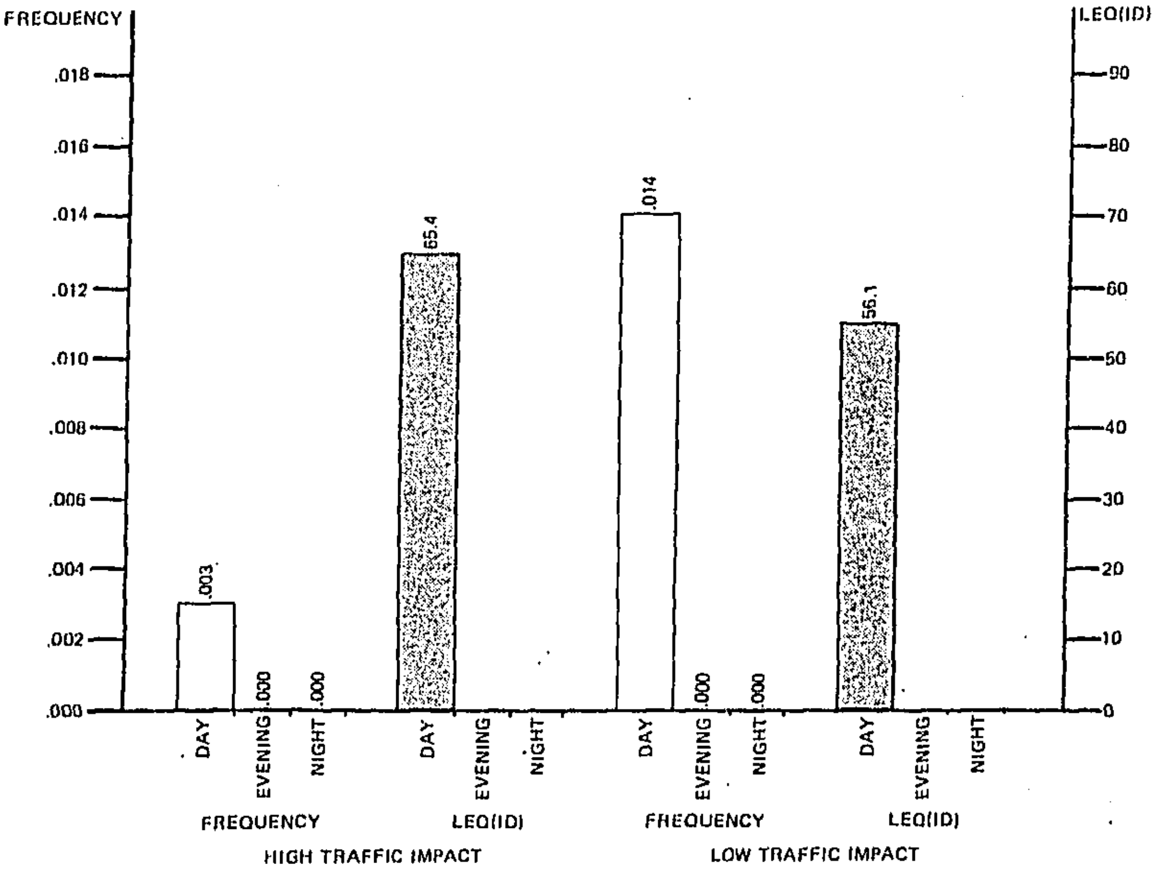


Figure 4-7D. Variations in Construction Contributions, by Time of Day

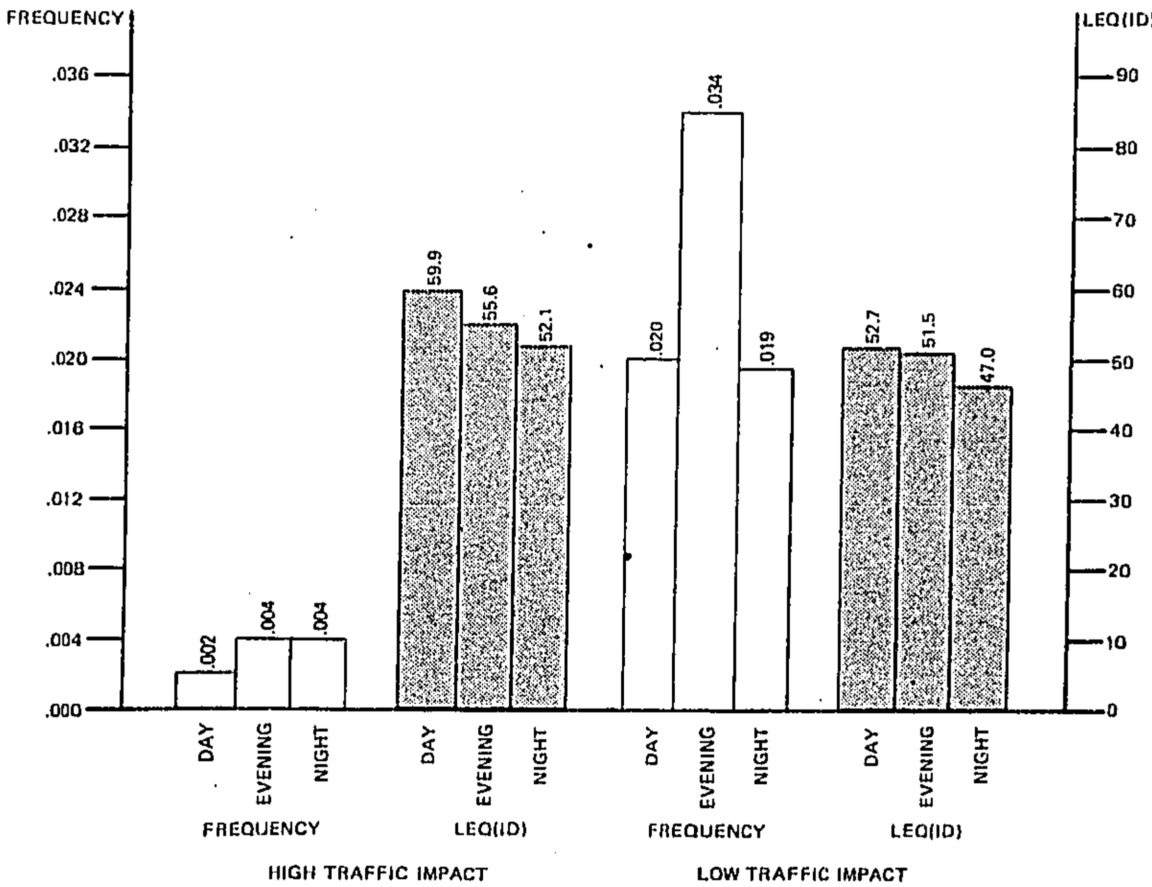


Figure 4-7E. Variations in Dog Contributions, by Time of Day

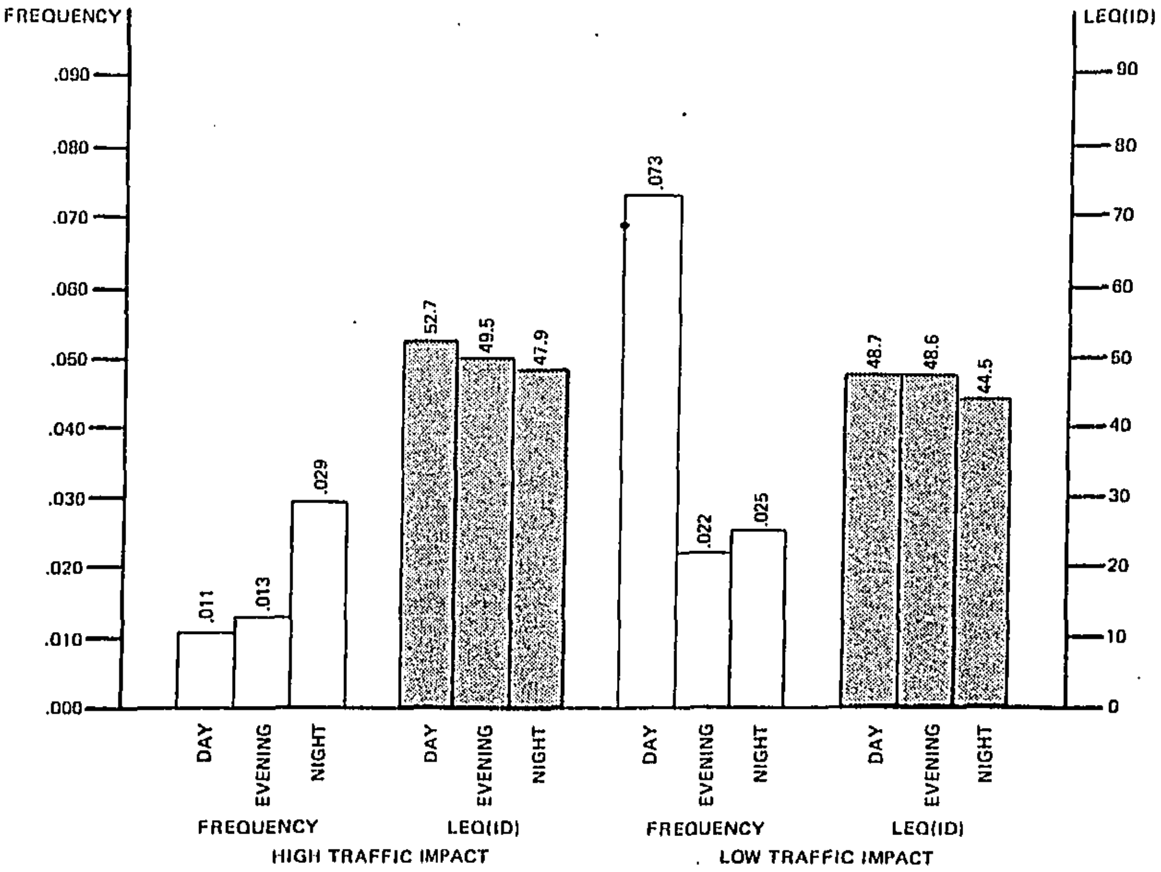


Figure 4-7F. Variations in Bird Contributions, by Time of Day

As expected, construction noise is usually present only during the daytime.

Dogs are very rarely heard in high-traffic-impact areas. In low-traffic-impact areas, they are heard equally frequently throughout the day, though their associated noise levels decrease during the nighttime.

Birds are somewhat louder in the daytime hours. Their frequency of identification in high-traffic-impact areas is greatest in the nighttime, while in low-traffic areas it is greatest in the daytime. This difference results from the stronger tendency of traffic in high-traffic-impact areas to drown out bird sounds during the daytime. Thus, the prominence of birds in high-traffic-impact areas is basically a function of the prominence of other competing sources, while in low-traffic-impact areas the temporal patterns of the birds themselves are more important.

From a policy perspective, these results suggest that roadway traffic abatement measures will have their greatest acoustical effects in the daytime and evening. This consideration must be balanced against the greater noise impacts which occur in the nighttime as predicted by the 10-dB weighting factor used in EPA criteria. With this factor included, roadway traffic during the nighttime would appear to be the most important contributor to adverse noise impacts. The penalty for nighttime sources is thus of critical importance in assessing the relative benefits of roadway traffic noise abatement measures over the temporal domain.

4-8 EFFECT OF URBAN AREA SIZE, POPULATION DENSITY, AND TRAFFIC IMPACT

4-8-1 Effect on Ldn

Table 4-4 shows summary statistics describing the Ldn measurement results in the 12 sampling cells described in chapter 3. The results indicate that average Ldn values are above the 55-dB threshold of impact in all 12 cells. Standard deviations of these levels are approximately 4 dB, suggesting that

Table 4-4. Summary Statistics of Ldn Measurement Results, by Sampling Cell

Traffic Impact	UA Size	UZ Density	n	Mean Ldn	Std. Dev.	Error of Mean
High	Large	High	5	69.2	4.4	2.0
High	Large	Medium-High	4	66.8	4.3	2.1
High	Medium-Small	High	5	67.6	2.1	0.9
High	Medium-Small	Medium-High	5	66.9	3.0	1.3
High	Medium-Small	Medium-Low	4	65.2	2.5	1.2
High	Medium-Small	Low	4	66.0	3.3	1.7
Low	Large	High	19	62.4	4.0	0.9
Low	Large	Medium-High	11	59.0	3.3	0.9
Low	Medium-Small	High	13	60.6	4.5	1.2
Low	Medium-Small	Medium-High	21	58.3	4.0	0.9
Low	Medium-Small	Medium-Low	26	58.2	4.3	0.8
Low	Medium-Small	Low	8	57.4	2.3	0.9

66 percent of the population within each cell are exposed to a residential Ldn within 4 dB of the average. Ninety percent are expected to be exposed to within 8 dB of the average Ldn.

The data reveal that the average residential noise exposure is sufficient to generate some adverse impact in all types of urban areas. While pockets of relative quiet certainly exist on the urban landscape, such areas must be viewed as exceptional even in low-density areas.

Inspection of table 4-4 indicates that traffic impact has a pronounced effect on residential noise levels, with the average Ldn in high-traffic-impact areas between 6 dB and 9 dB greater than in low-traffic-impact areas.

Analysis of the variation in Ldn over urban area size and urban zone density reveals that density is the other significant factor. Its effect is best represented when the logarithm of the actual density is used as the independent variable instead of the density category used to define the sampling cell structure. Urban area size is a significant factor only insofar as it correlates with urban zone density: noise levels in large urban areas are higher as a result of the greater population densities of these areas.

A regression analysis of the results indicates that a simple and reasonably accurate prediction of Ldn is given by:

$$\text{Ldn} = 42.3 + 4.7 \times (\log_{10} \text{UZ density}) + 7.9 \times (\text{Traffic})$$

where UZ density is the urban zone population density, and,

Traffic = 1 for high-traffic-impact

= 0 for low-traffic-impact

The standard deviation of the data from the regression line is 3.7 dB. Variation in the independent variables of traffic impact and Ldn accounts for approximately half of the variation in Ldn found in the survey.

The regression formula and its standard deviation may be used to predict population distributions over Ldn in areas of varying traffic impact and population density. Table 4-5 indicates the predicted percentages of population exposed over certain values of Ldn as a function of traffic impact and population density. Examples of urban zones of various densities are also included.

Table 4-5 shows that virtually the entire population exposed to Ldn over 75 dB in their residential environment resides in high-traffic-impact areas (except, of course, for those so exposed as a result of aircraft noise). This is important because 75 dB represents "full" noise impact, and represents the threshold at which auditory damage may begin to occur as a result of residential exposure. Attempts to protect this highly impacted population should thus focus almost entirely on areas within 100 feet of arterials or 300 feet of freeways.

In conclusion, variation in Ldn as a function of traffic impact, urban area size, and urban zone density is significant, but rarely extends below the 55-dB threshold of impact. Sources of the variation include traffic impact and urban zone density, with the former having a more pronounced effect. The small population that is fully impacted according to EPA criteria resides almost exclusively in high-traffic-impact areas.

4-8-2 Effect on Source Contributions

Figures 4-8A through 4-8L show average frequency and Leq (id) values obtained for each source in each of the 12 sampling cells. These values are based on measurements taken at the front only.

Source contributions were found to vary greatly from site to site. The average values indicated in figures 4-8A through 4-8L must, therefore, not be

Table 4-5. Cumulative Population Distributions Over Ldn by Traffic Impact and Urban Zone Density

Ldn	Traffic Impact	Percent of Population Exposed					
55	High	99%	100%	100%	100%	100%	100%
	Low	65	78	86	93	97	98
60	High	87	94	97	98	100	100
	Low	17	28	39	56	72	83
65	High	42	58	69	83	91	96
	Low	1	3	5	12	22	35
70	High	6	12	20	34	50	65
	Low	0	0	0	1	2	4
75	High	0	1	1	4	9	17
	Low	0	0	0	0	0	0
Population Density (thousands per square mile)		1	2	4	8	16	32
Example Urban Zones		Leominister, MA	Newport News, VA	Outside Central City Washington, DC	Lancaster, PA	Chicago, IL	New York City

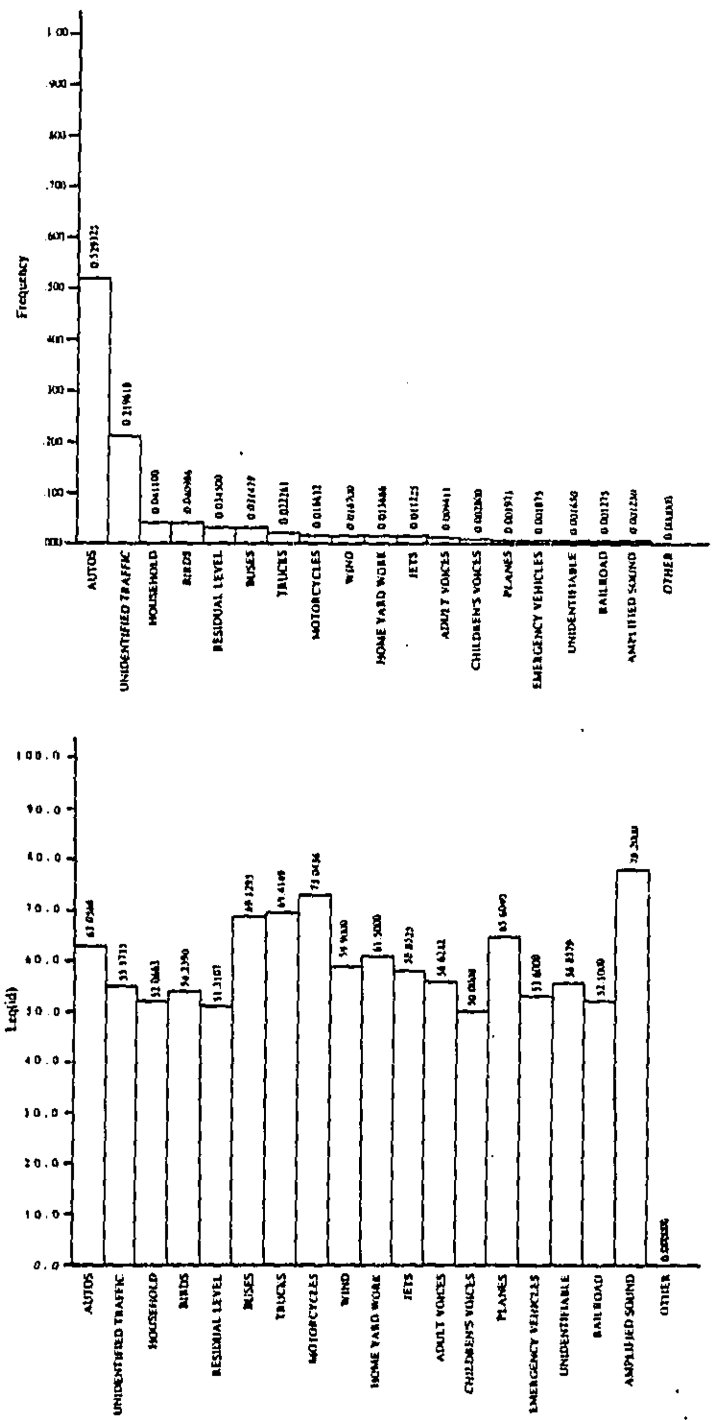


Figure 4-8A. Source Contribution Profile - Large, High-Density, High-Traffic-Impact Areas

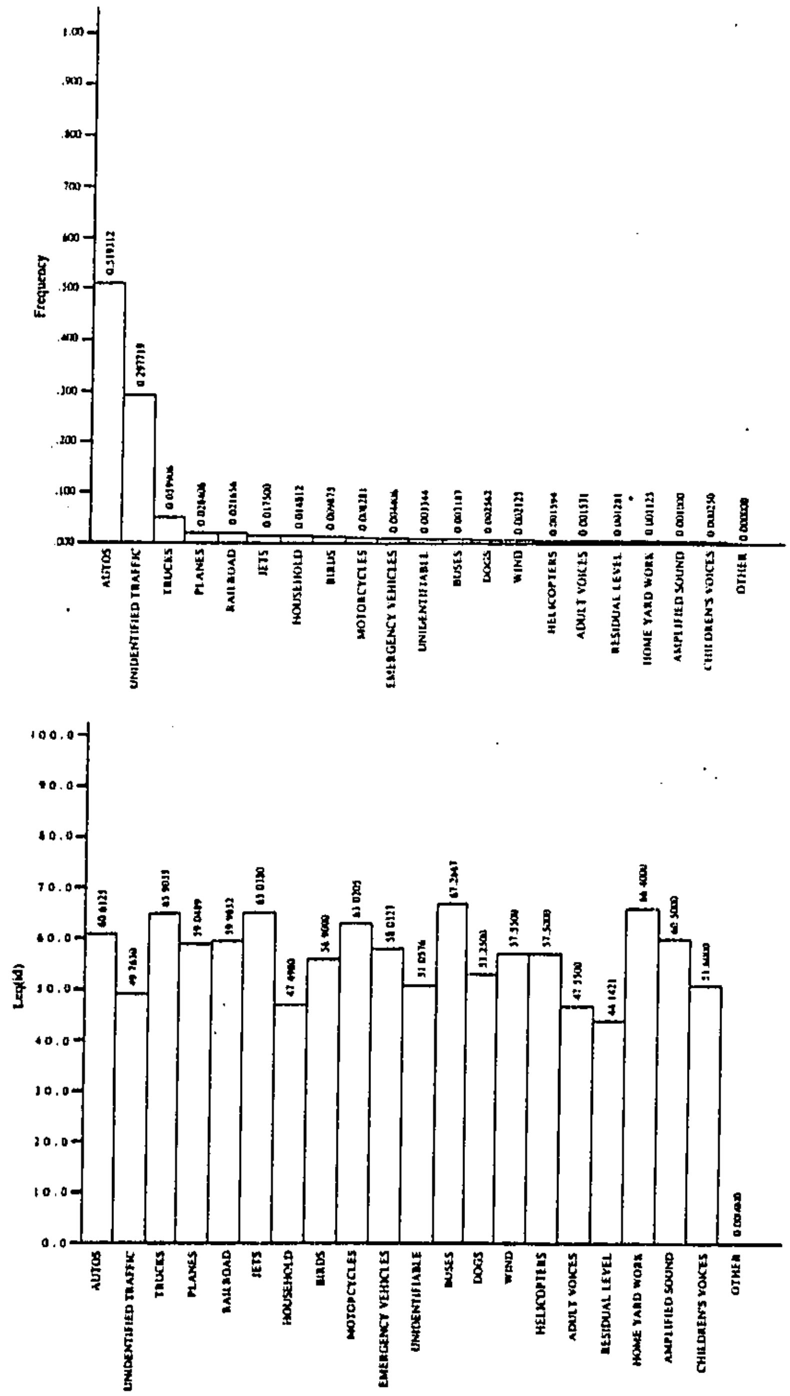


Figure 4-8B. Source Contribution Profile - Large, Medium-High-Density, High-Traffic-Impact Areas

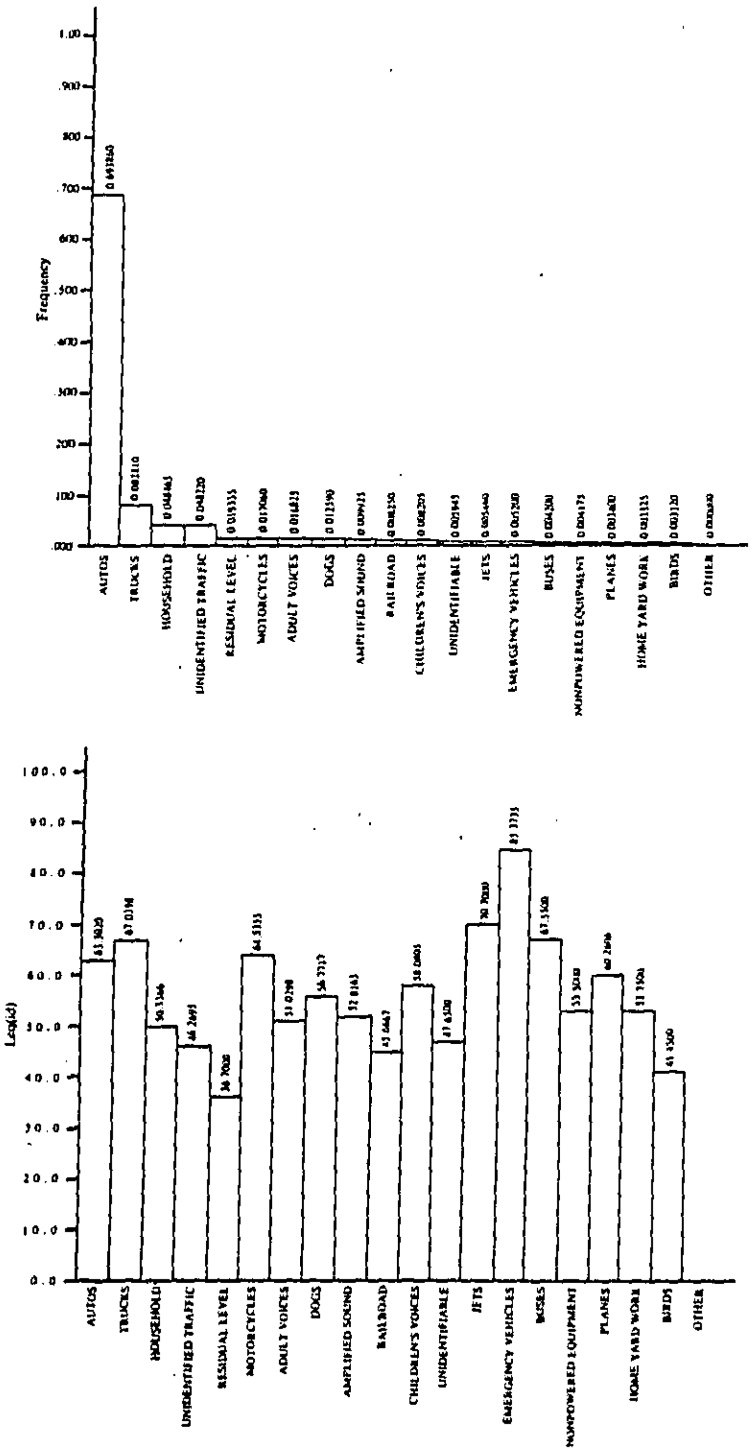


Figure 4-8C. Source Contribution Profile - Medium-Small, High-Density, High-Traffic-Impact Areas

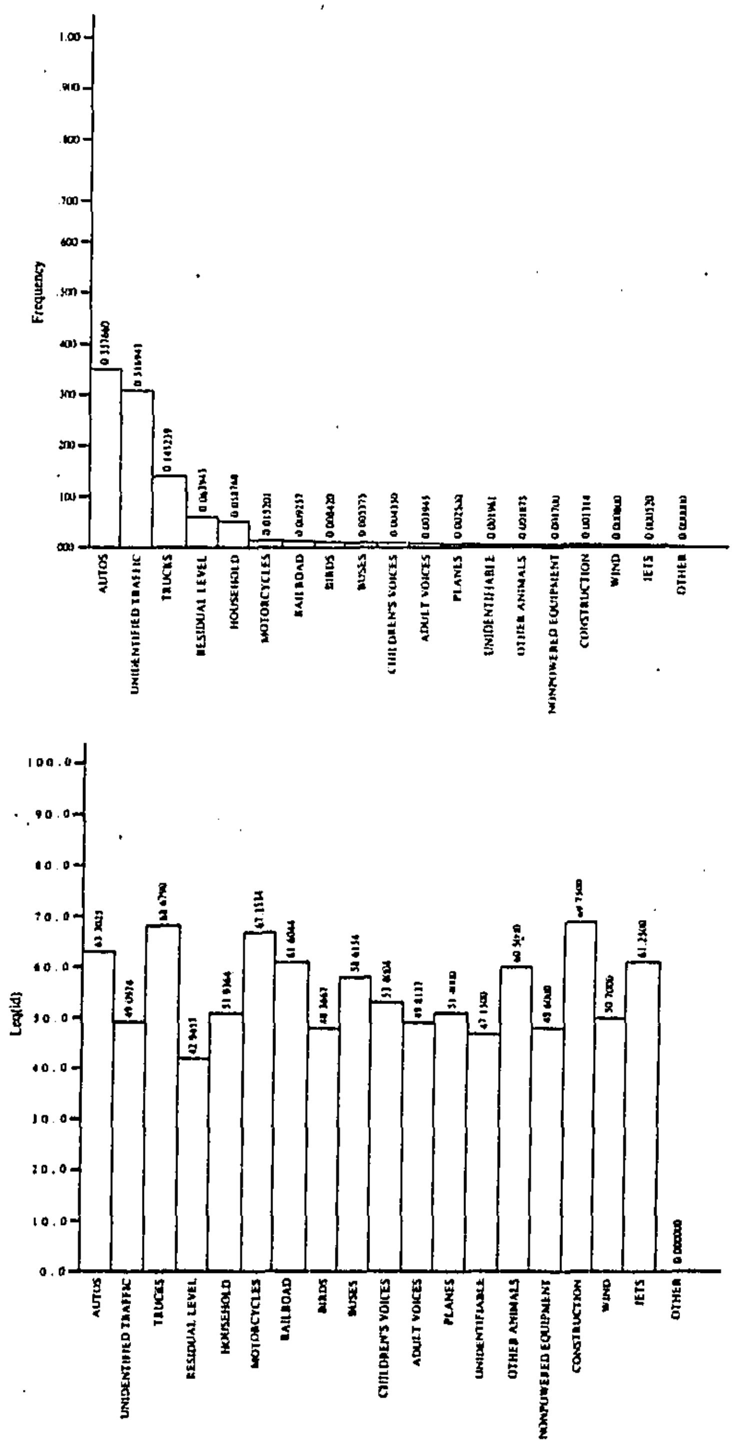


Figure 4-8D. Source Contribution Profile - Medium-Small, Medium-High-Density, High-Traffic-Impact Areas

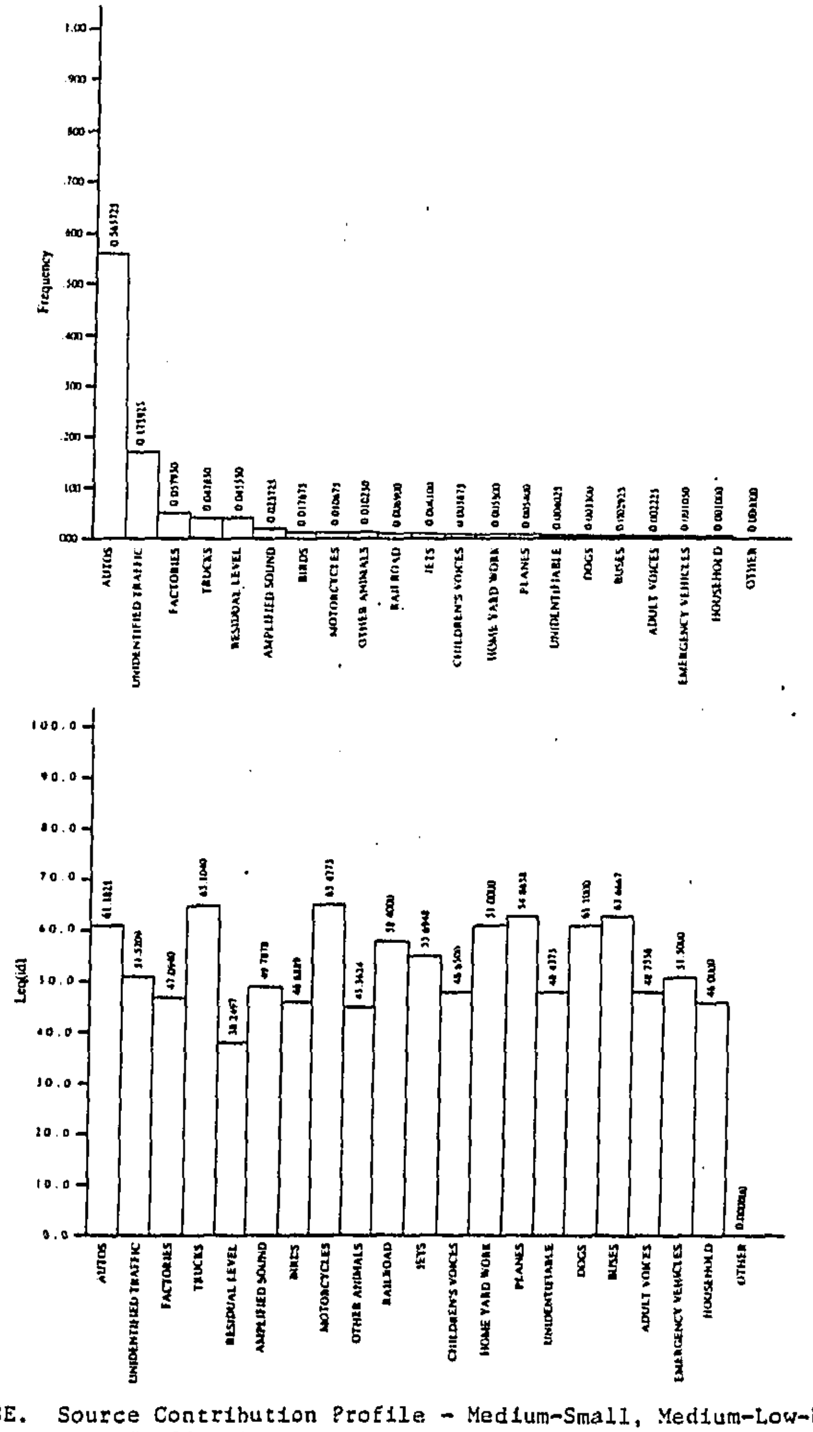
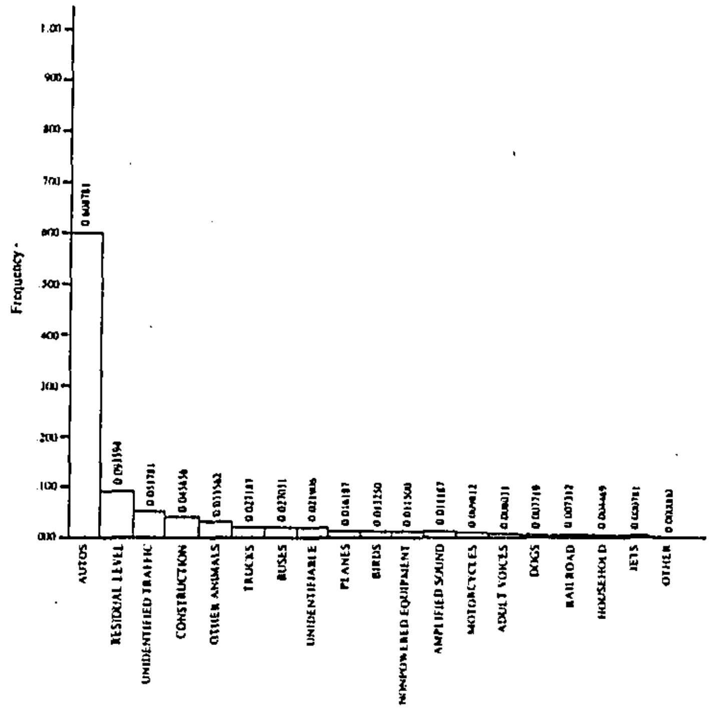


Figure 4-8E. Source Contribution Profile - Medium-Small, Medium-Low-Density, High-Traffic-Impact Areas



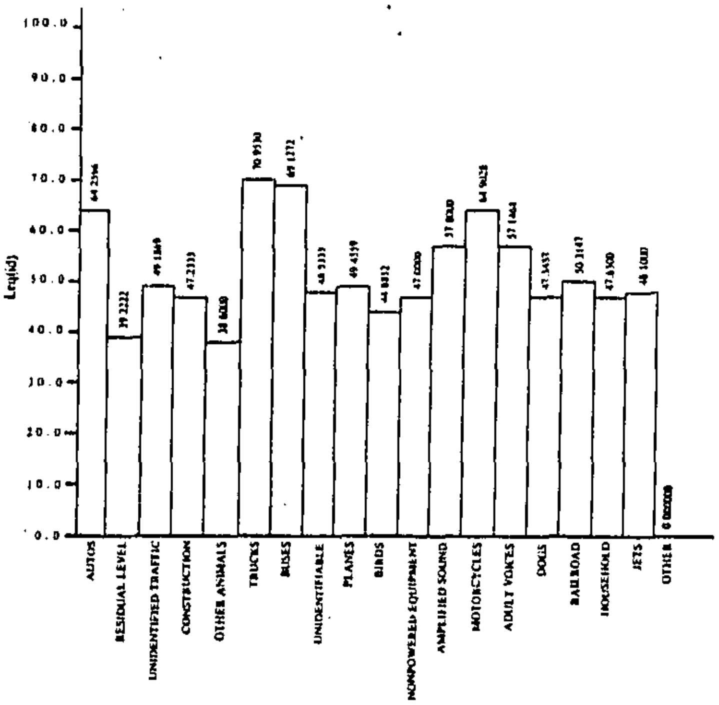
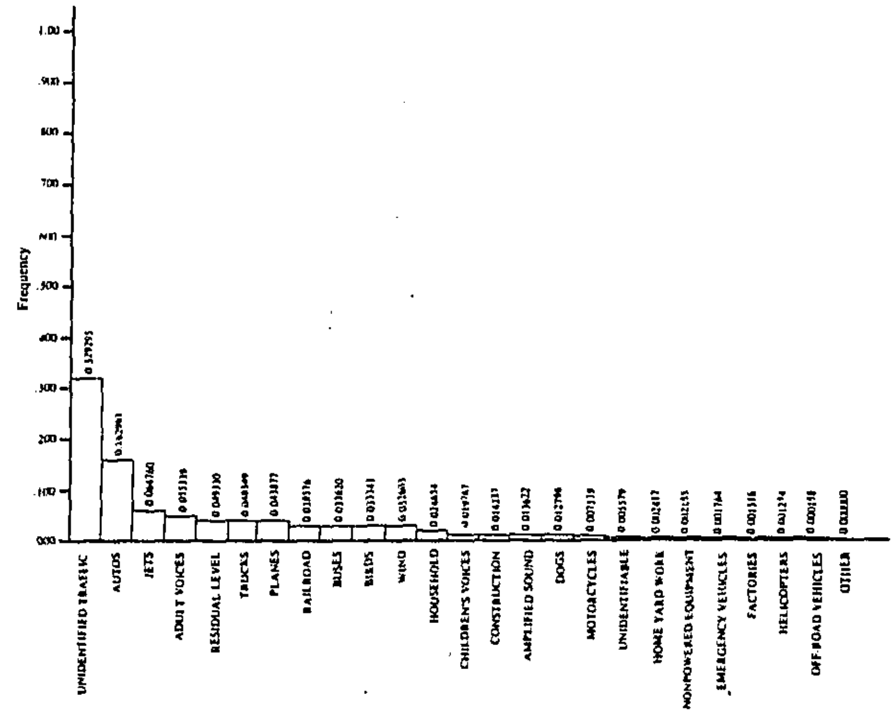


Figure 4-8F. Source Contribution Profile - Medium-Small, Low-Density, High-Traffic-Impact Areas



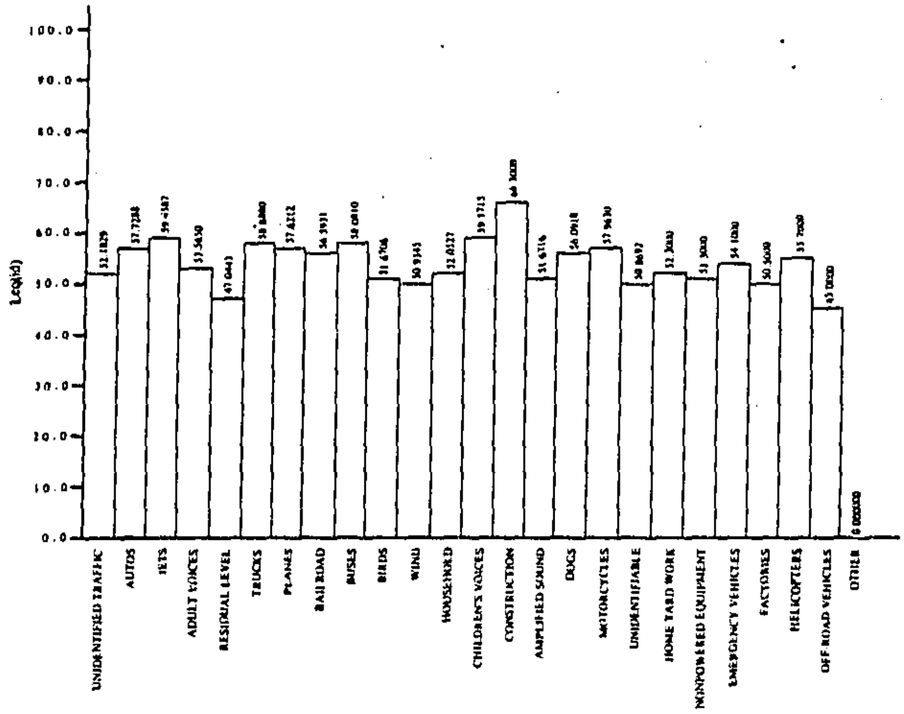
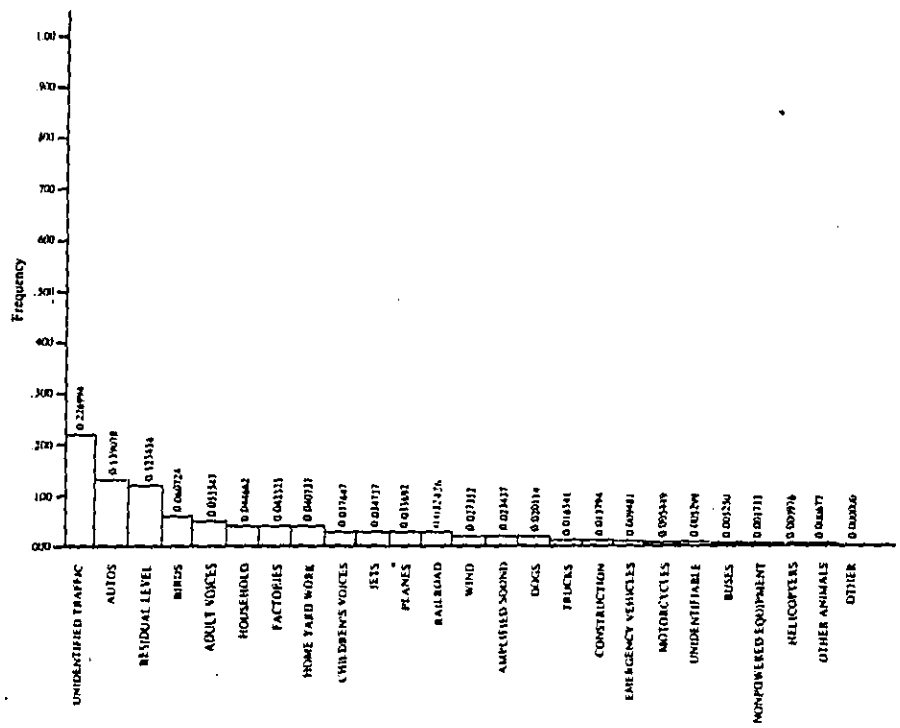


Figure 4-8G. Source Contribution Profile - Large, High-Density, Low-Traffic-Impact Areas



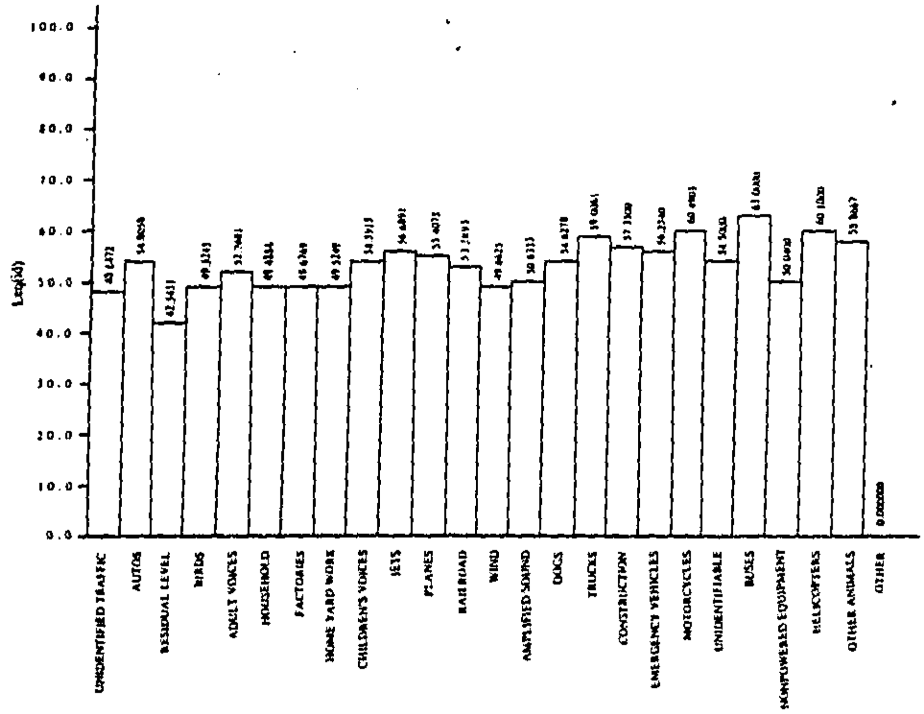


Figure 4-8H. Source Contribution Profile - Large, Medium-High-Density, Low-Traffic-Impact Areas

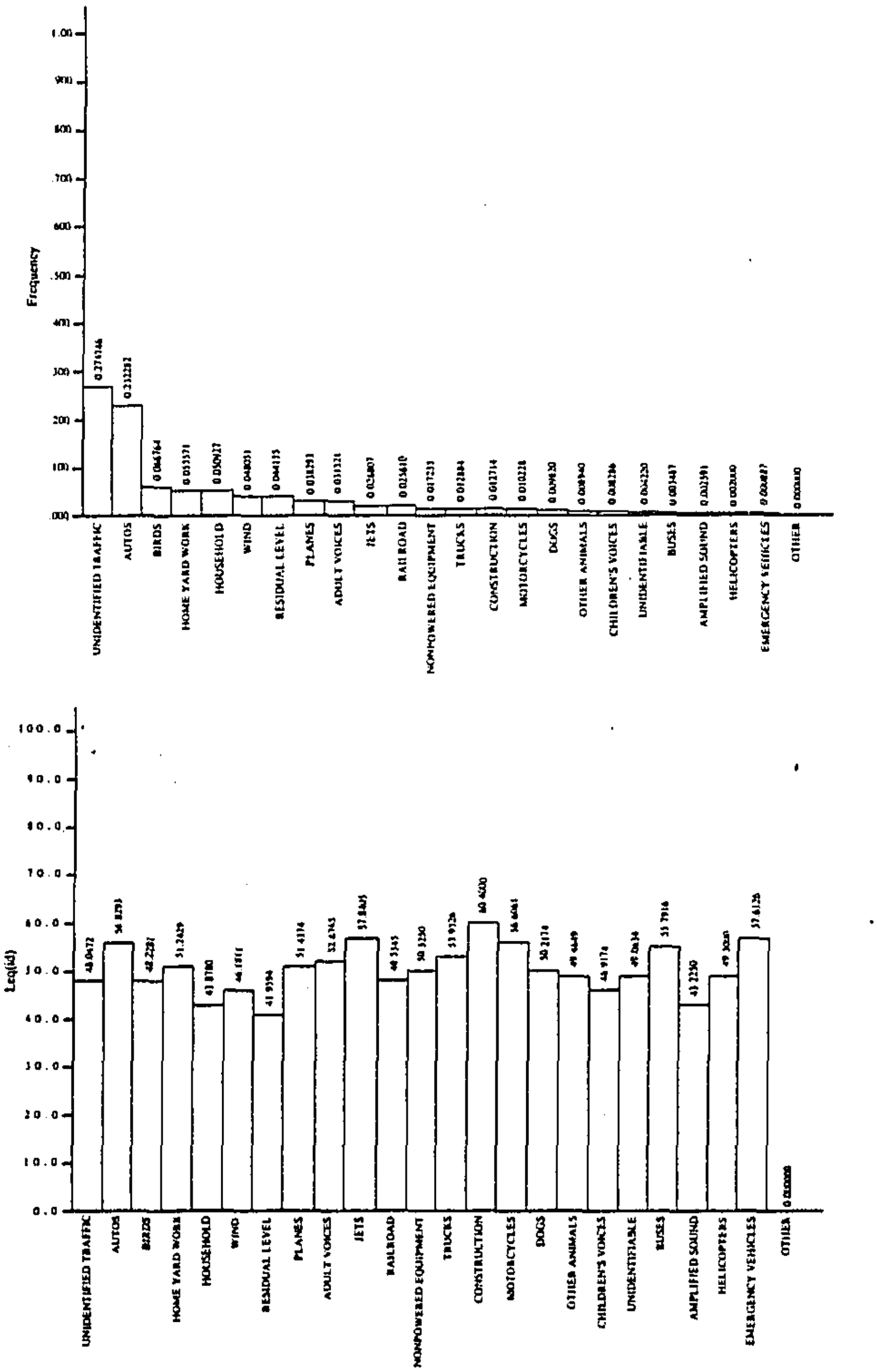
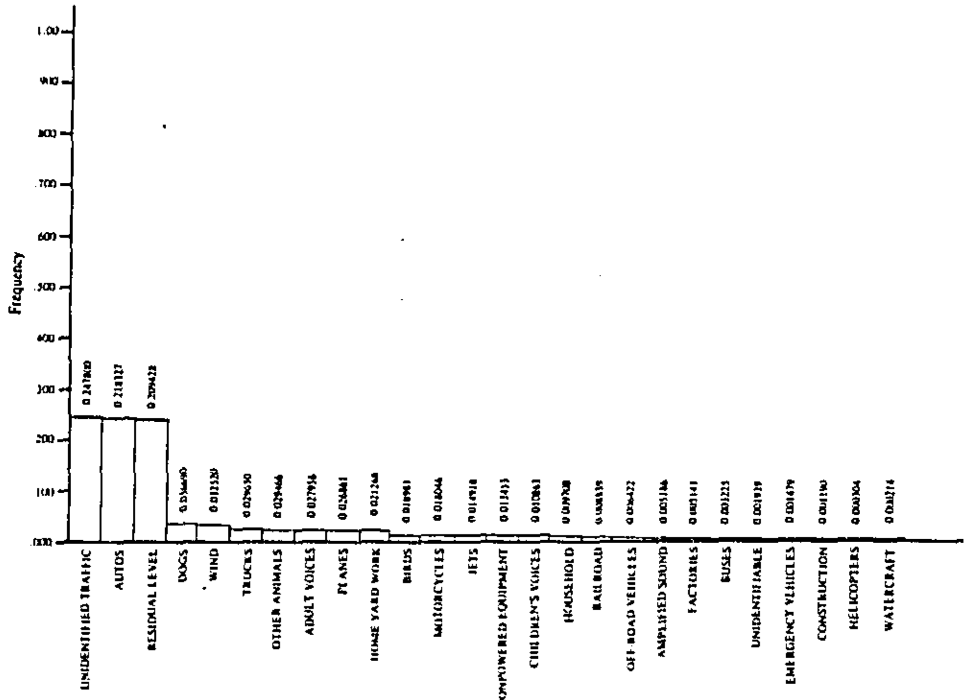


Figure 4-81. Source Contribution Profile - Medium-Small, High-Density, Low-Traffic-Impact Areas



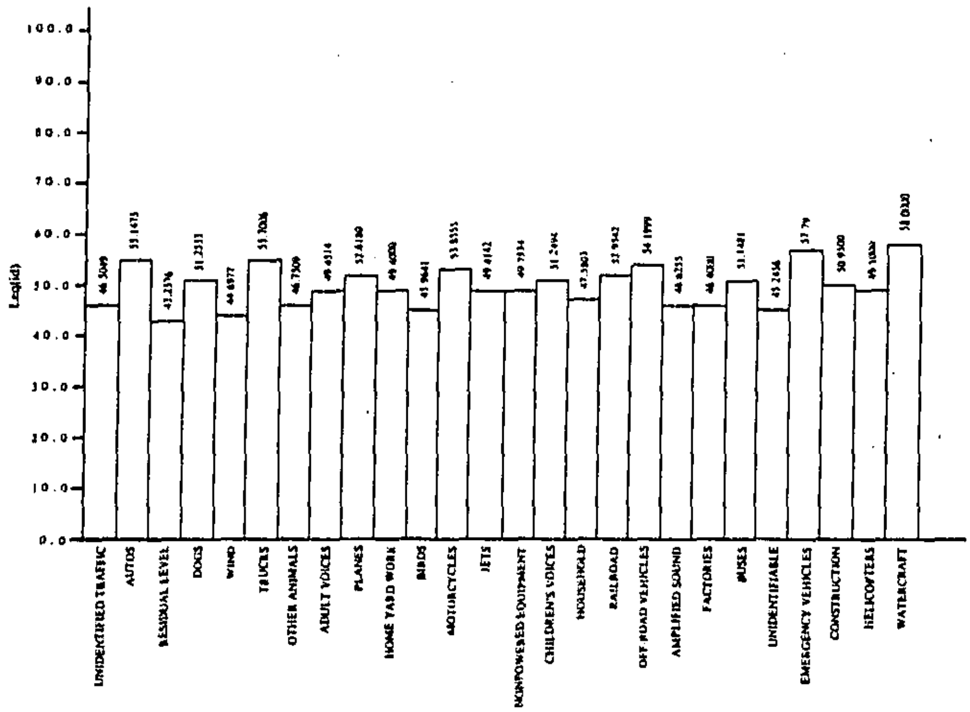


Figure 4-8J. Source Contribution Profile - Medium-Small, Medium-High-Density, Low-Traffic-Impact Areas

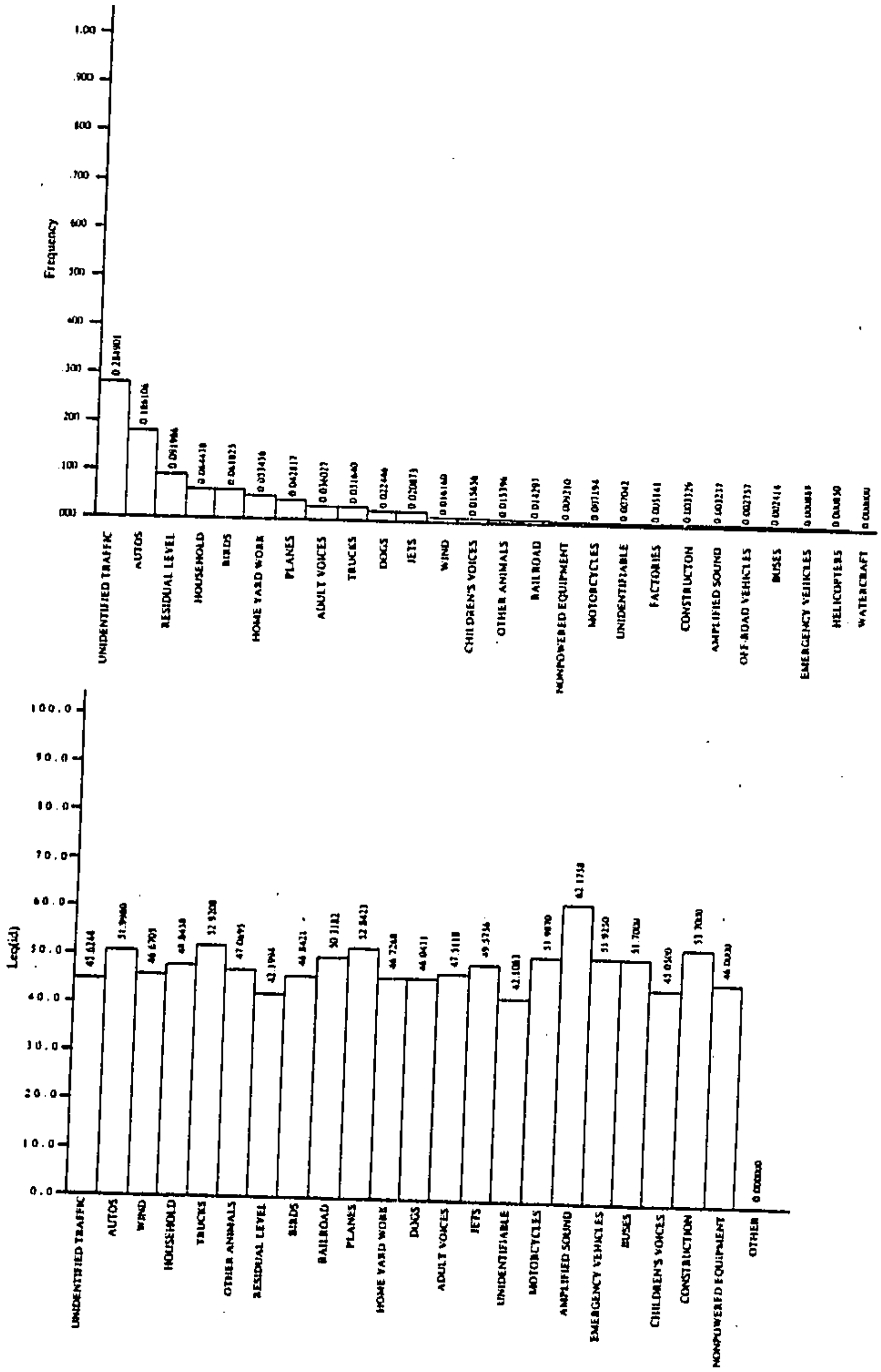


Figure 4-8K. Source Contribution Profile - Medium-Small, Medium-Low-Density, Low-Traffic-Impact Areas

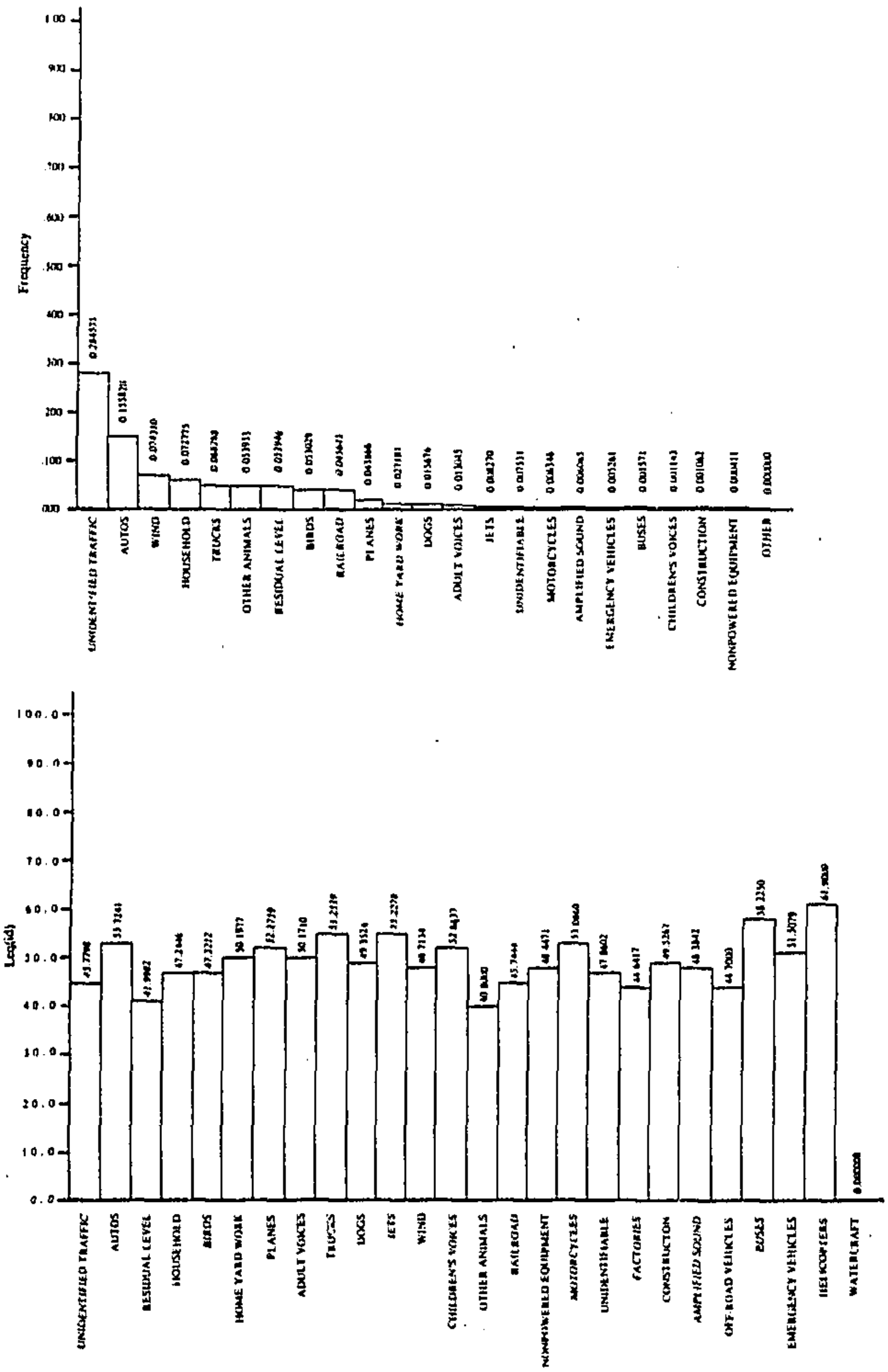


Figure 4-8L. Source Contribution Profile - Medium-Small, Low-Density, Low-Traffic-Impact Areas taken as predictors of these contributions at any particular site. Local factors not considered in the survey sampling cell structure would have to be considered in the development of such predictors. Nonetheless, these results justify some tentative conclusions regarding the variation in source contributions that does result from variation in the cell structure parameters.

The dominance of roadway traffic sources is evident throughout these results. As expected, this dominance is less pronounced in low-traffic-impact areas. Such areas are seen to have a generally more diverse noise environment.

Autos, trucks, motorcycles, construction, dogs, and birds were selected for analysis of variation with respect to traffic impact, urban area size, and population density. It was found that frequencies of identification are strongly affected by traffic impact, but not by population density. Leq (id) values are generally affected both by traffic impact and by population density.

As expected, autos, trucks, and motorcycles are identified more frequently in high-traffic areas. Construction, dogs, and birds are identified less frequently. This is shown in figure 4-9.

Figure 4-10 shows the regression lines obtained when, for each of the six sources, the dependent variable Leq (id) is plotted against the log of the population density. Density is seen to have more of an effect on roadway source levels in low-traffic-impact areas. In the case of construction, density has a pronounced effect regardless of traffic impact. For dogs and birds, the effect is less pronounced, but again independent of traffic impact.

A similar analysis was also performed in which the dependent variables were the aggregate contributions of four classes of sources: roadway traffic, aircraft, other abatable sources, and nonabatable sources. The sources included in these classes are shown in table 4-6, and the results of the regression analysis in table 4-7. It was found that both traffic impact and urban zone

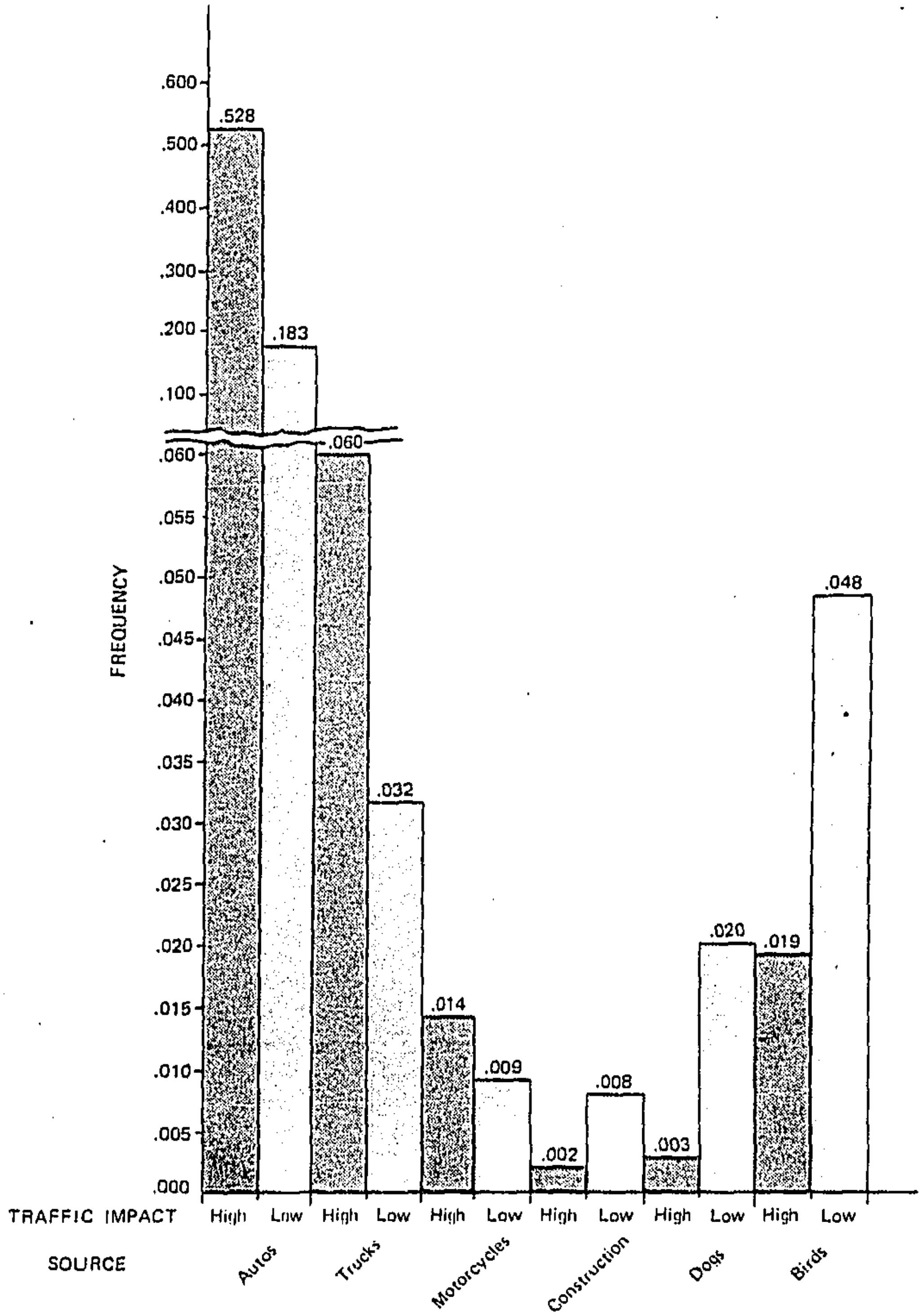


Figure 4-9. Frequency of Identification for Selected Sources - High- and Low-Traffic-Impact Areas

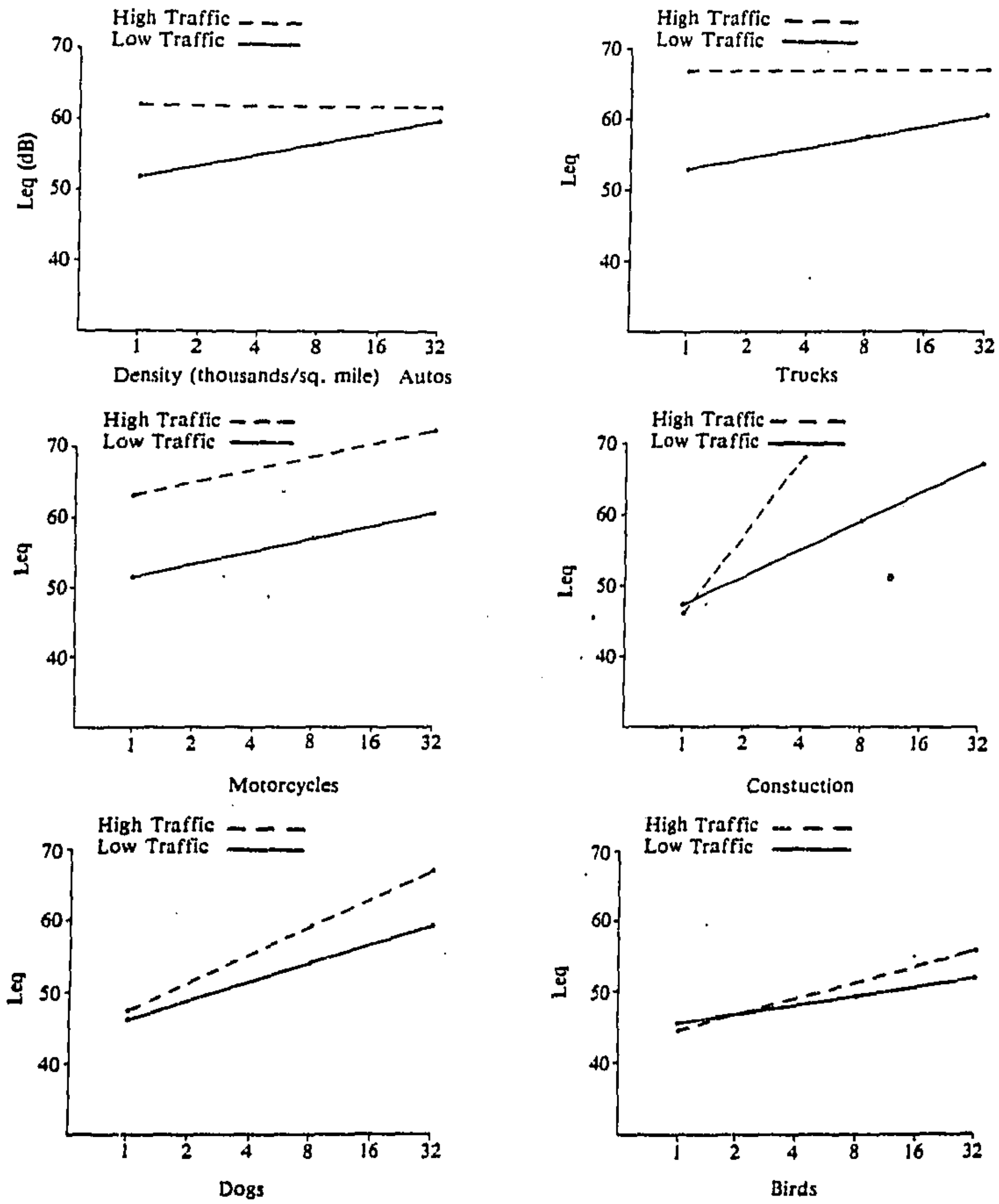


Figure 4-10. Regression Lines - Leq (id) vs. Log 10 (UZ density) - For Selected Sources, High- and Low-Traffic-Impact Areas

Table 4-6. Source Classes

Roadway Traffic	Aircraft	Other Abatable Sources	Nonabatable Sources
Autos	Jets	Construction	Household
Trucks	Planes	Factories	Nonpowered Equipment
Buses	Helicopters	Off-road Vehicles	Residual
Motorcycles		Water Vehicles	Dogs
Emergency Vehicles		Amplified Sound	Birds
Unidentified Traffic		Home Yard Work	Other Animals
		Railroads	Wind
			Child Voice
			Adult Voice
			Unidentifiable

Table 4-7. Summary of Regression Results - Source Class Contributions

		High Traffic				Low Traffic			
	Source Type	Intercept	Density Coefficient	Probability of Significance	R^2	Intercept	Density Coefficient	Probability of Significance	R^2
Frequency	Roadway Traffic	.57	.07	0.32	.039	0.16	0.10	.89	.027
Frequency	Aircraft	.013	.00005	0.04	.000085	-0.06	0.03	.93	.036
Frequency	Other Abatable Sources	.21	-0.04	0.82	.067721	.21	-0.03	.70	.012
Frequency	Non-abatable Sources	.20	-0.02	0.29	.005	0.68	-0.10	.96	.031
Leq (id)	Roadway Traffic	61.0	.72	0.22	.003	33.9	5.44	.99	.13
Leq (id)	Aircraft	14.7	12.6	0.99	.26	38.0	4.7	.99	.075
Leq (id)	Other Abatable Sources	27.7	7.9	0.84	.11	26.3	7.0	.99	.14
Leq (id)	Non-abatable Sources	18.8	8.9	0.97	.16	25.6	6.9	.99	.200

Predicted value = Intercept + (Density Coefficient) x log 10 (urban zone density)

Probability of Significance - The probability, based on the observed data, that urban zone density is statistically significant.

R^2 - The amount of variation in the dependent variable (Frequency or Leq (id)) which is accounted for by variation in the independent variable (log 10 urban zone density).

density are significant factors to frequencies of identification of these classes, especially in low-traffic-impact areas. Roadway traffic and aircraft source identifications increase with frequency, while other abatable sources and nonabatable sources identifications decrease. Leq (id) values of all classes increase with density in both high- and low-traffic-impact areas, with the exception of roadway traffic in high-traffic-impact areas, where no significant relationship is found.

In conclusion, traffic impact and population density significantly affect the source composition of the residential noise environment. Traffic impact is the most important factor in determining the frequencies of identification of noise sources. Population density is also somewhat significant to these frequencies when classes of sources are considered. Both density and traffic impact are significant in determining noise levels associated with either individual sources or classes of sources; these levels increase with population density.

4-9 SUMMARY OF RESULTS

Noise pollution is a problem to which the vast majority of the urban population is subject. It is most of all a problem in high density areas, and in areas located near major roadways, but remains considerable in areas with neither of these characteristics.

Noise levels vary significantly both temporally and locationally. The highest levels occur in the daytime but, if the EPA 10-dB weighting factors for nighttime noise is considered, the greatest impacts occur at the beginning and end of the nighttime. Higher levels also occur at the front of residential units. To the extent that noise control programs can be focused spatially and temporally, these considerations should be used as a guide to such focusing.

Roadway traffic is the most significant noise source, and should be the primary target of noise control programs. In areas located near major roadways, roadway sources should be targeted almost exclusively. In other areas, noise from other sources is also significant, and becomes more so with greater population density. In areas not near major roadways, the severity of noise is associated with the number of significant noise sources, and thus the degree of the noise problem with the complexity of its solution.

APPENDIX A

METHODOLOGY SUPPLEMENT

A-1 INTRODUCTION

The site selection procedures, measurement protocol, and analytical procedures used in the National Ambient Noise Survey were summarized in chapter 3. More detailed information on these topics is presented here.

A-2 SITE SELECTION

The urban population, defined for the purpose of the survey as the population residing within urbanized areas, was divided into 12 subpopulations on the basis of urban area size, urban zone population density, and traffic impact. In the selection of measurement sites, the objective was to obtain random samples of residential units of these subpopulations. This was a five-step process. First, a quota of sites was established for each cell. Second, appropriate numbers of large and medium-small urban areas, and urban zones within them, were randomly selected. Third, census tracts were randomly selected within each selected urban zone. Fourth, blocks were randomly selected within each census tract. Finally, residential units, either high- or low-traffic impact units as required, were randomly selected within each block.

Within this basic site selection framework, a fair amount of procedural flexibility was considered appropriate to the pilot-like nature of the study. As a result, a number of changes in procedural detail were made between the first and second years of the study. In recognition of the fact that the site selection framework, rather than the particular procedures followed within that framework, is more important, the site selection process will be described on a step-by-step basis with year-to-year differences noted for each step.

A-2-1 Establishing Site Quotas

The use of measurement resources allows considerable flexibility in the allocation of measurement resources. (This ability had already made it possible to systematically exclude high-aircraft-impact sites.) Two objectives might be considered in exercising this flexibility. The first is to optimize the sample distribution from the point of view of assessing the significance of various parameters used in the cell structure to the variables of interest (e.g., determining the effect of urban area size on Ldn). The second is to optimize the sample distribution from the standpoint of establishing a maximally accurate statistical profile of the population as a whole (e.g., determining as accurately as possible the average Ldn value to which residents are exposed). The first objective is best served by distributing measurement sites evenly among the sampling cells. The second objective suggests a distribution which is a function of the cell populations.

In the first year of the study, the focus was upon the first objective, and the sites were therefore distributed evenly. Four sites were allocated to each of the 12 sampling cells.

In the second year emphasis was given to achieving maximally accurate national estimates. Thus, in the second year, sites were apportioned according to cell populations. The small populations of the high-traffic cells resulted in a second-year allocation that emphasized much more strongly the low traffic cells. The cell quotas, along with the numbers of sites actually obtained, are given in table A-1.

Table A-1. Site Quotas and Sites Obtained for Each Sampling Cell

Urban Area Size	Urban Zone Density	Traffic Impact	1980 Quota	1980 Obtained	1981 Quota	1981 Obtained	Total Quota	Total Obtained
Large	High	High	4	4	1	1	5	5
Large	High	Low	4	4	16	15	20	19
Large	Medium-High	High	4	4	1	0	5	4
Large	Medium-High	Low	4	4	11	7	15	11
Medium-Small	High	High	4	4	1	1	5	5
Medium-Small	High	Low	4	4	11	9	15	13
Medium-Small	Medium-High	High	4	3	1	1	5	4
Medium-Small	Medium-High	Low	4	3	21	18	25	21
Medium-Small	Medium-Low	High	4	3	1	1	5	4
Medium-Small	Medium-Low	Low	4	4	26	22	30	26
Medium-Small	Low	High	4	3	1	1	5	4
Medium-Small	Low	Low	4	3	6	5	10	8
Total			48	43	97	81	145	124

A-2-2 Selecting Urbanized Areas and Urban Zones

The next objective was to select residential units to fill the cell quotas established. To limit travel costs, the residential units were clustered in certain randomly selected residential areas. This clustering was balanced against the need to obtain nationally representative results.

In the first year of the study, the equal apportionment of sites among the sampling cells suggested a straightforward approach to accomplishing the desired clustering. This was to select initially eight urbanized areas, called primary areas, four in large urbanized areas and four in medium-small urbanized areas. One site in each of the four large urban area cells was selected in each primary large urbanized area. When possible, the analogous procedure, this time involving the four medium-small urbanized area cells, was performed for the primary medium-small urbanized areas. In fact, most medium-small urbanized areas do not contain urban zones in each of the four categories of population density. This necessitated two procedural refinements. First, urbanized areas close to the primary areas, and having populations on the same side of 200,000 as the primary areas, were selected to provide the sites not available in the primary areas. Second, a 10-percent leeway was allowed when necessary: An urban zone with a density as high as 3,300 persons per square mile or as low as 1,350 persons per square mile could be counted as medium-low density and likewise for the other density categories.

To further insure that the sample of urbanized areas was representative of such areas in the United States, two additional constraints were imposed upon the urbanized area selection. First, it was decided that one medium-small and one large urbanized area be located in the west, south, northcentral, and northeast geographical regions of the United States. Second, for the medium-small urbanized areas, it was determined that two of the selected areas would have a population over 200,000 and two have a population under 200,000. With these requirements taken into account, the urbanized areas were selected at random from the list compiled by the 1970 census.

In the second year, urbanized area and urban zone selection procedures were modified as the result of a number of considerations. These included the unequal allocation of sites to sampling cells used in the second year; a belief that further clustering was possible in urbanized areas and urban zones of large population; and a desire to insure that the larger population centers in each urbanized area size category, along with those regions of the country with a greater urbanized population, have a more proportionate representation in the sample. To accommodate these factors, the following changes were made:

a. An urban zone was allowed to contain at least two measurement sites, with an additional two sites for each million of population (an urban zone with a population between one and two million could have four sites).

b. The random selection process was conducted on a population-weighted basis, so that the probability of a certain urbanized area being selected was proportional to its population.

c. No geographical quotas, and no quotas concerning urbanized areas with populations greater or less than 200,000, were set.

Large and medium-small urbanized areas were selected on a one-by-one basis following the random selection process described in (2), above. Each selected area was made the locus of as many sites as was consistent with (1), above, subject to the limitation of the cell quotas specified in table A-1. This process continued until all site quotas were achieved. At this point sites in urban zones in which more than one site was located were transferred, when possible, to urbanized zones in the same density category in other urbanized areas which had been selected after the quota for that category had been filled.

The refined urbanized area selection procedure used in the second year is preferable from the standpoints of conceptual simplicity and the representiveness of the generated sample. There is no evidence, however, that the slight biases inherent in the first-year procedure have any acoustical significance. Thus, it is assumed that on a cell-by-cell basis, the data acquired in the first year is completely comparable with the second.

A-2-3 Selecting Census Tracts and Blocks

According to the U.S. Census, "census tracts are small areas into which large cities and metropolitan areas are divided for statistical purposes." These tracts are in turn divided into blocks. A block is usually a well-defined rectangular piece of land bounded by streets or roads. A typical tract has a population of between 1,000 and 10,000; a typical block has a population between 50 and 500. These divisions provided a convenient basis for carrying the site-selection process from the urban zone level to a higher level of specificity.

The United States Census Bureau publishes a set of census tract and block statistics, along with a set of maps that contain these divisions, for each urbanized area. Figure A-1 shows a typical page of block statistics. The outermost numbers correspond to census tracts, the numbers beneath them to blocks within those tracts. Figure A-2 shows the census map of the area described in figure A-1. The larger outlined areas are census tracts; the smaller areas within them are blocks. Urban zone boundaries are also identified on the maps.

Table 2. **Characteristics of Housing Units and Population, by Blocks: 1970**—Con. **Fresno County, Calif.**

[Data exclude vacant seasonal and vacant migratory housing units. For minimum base for derived figures (percent, average, etc.) and meaning of symbols, see text]

Blocks Within Census Tracts	Total population	Percent of total population: Negro	Percent of total population: In group quarters	Percent of total population: Under 18 years	Percent of total population: 62 years and over	Year-round housing units: Total	Year-round housing units: Lacking some or all plumbing facilities	Units in—: One-unit structures	Units in—: Structures of 10 or more units	Occupied housing units, Owner: Total	Owner: Lacking some or all plumbing facilities	Owner: Average number of rooms	Owner: Average value (dollars)	Owner: Percent Negro	Renter: Total	Renter: Lacking some or all plumbing facilities	Renter: Average number of rooms	Renter: Average contract rent (dollars)	Renter: Percent Negro	1.01 or more persons per room: Total	1.01 or more persons per room: With all plumbing facilities	One-person households	With female head of family	With roomers, boarders, or lodgers
55	1584	1	-	39	7	468	14	449	-	322	5	5.8	27100	1	113	2	4.5	73	-	47	45	37	18	11
902	27	-	-	41	9	6	-	6	-	5	-	4.0	...	-	1	...	...	...	-	-	-	-	-	-
903	8	-	-	-	-	4	...	...	...	...	...	...	...	-	...	...	...	...	-	...	...	...	...	...
904	25	-	-	56	8	6	-	6	-	5	-	5.6	...	-	1	...	...	...	-	1	1	1	-	-
905	51	4	-	45	4	14	-	14	-	9	-	6.1	25000	-	3	...	...	...	...	1	1	1	-	-
906	47	-	-	43	4	12	-	12	-	10	-	5.4	21500	-	2	...	...	...	...	1	1	1	1	-
907	26	-	-	39	-	8	1	8	-	6	-	5.7	27100	-	1	...	...	...	-	1	1	-	-	-
908	24	-	-	47	8	6	-	6	-	6	-	5.3	-	-	-	-	-	-	-	-	-	-	-	-
909	23	-	-	26	13	7	-	7	-	6	-	5.7	...	-	1	...	...	...	-	-	-	-	1	-
910	42	-	-	29	17	14	-	13	-	3	...	...	...	-	8	-	5.3	...	-	2	2	1	-	1
911	26	-	-	50	-	5	-	5	-	-	-	-	-	-	5	-	5.0	...	-	2	2	-	-	-
912	106	-		45	3	25	-	25	-	19	-	5.9	25500	-	6	-	4.3	...	-	6	6	-	1	-
913	8	-	-	50	25	2	...	...	...	...	...	...	...	-	...	...	...	...	-	...	...	...	...	...
914	76	-	-	43	3	22	1	21	-	18	1	5.6	26500	-	1	...	...	...	-	3	2	-	-	-
915	64	-	-	52	6	15	-	15		13	-	5.5	21600	-	2	...	...	...	-	3	3	-	-	1
916	50	-	-	35	7	19	1	17		15	1	6.4	23900	-	2	...	...	...		-	-	1	-	-
917	45	-	-	47	4	11	-	11	-	8	-	6.1	...	-	2	...	...	...	-	2	2	-	-	1
918	64	-	-	42	3	20	1	19	-	15	-	5.4	21000	-	3	...	...	...	-	-	-	1	-	-
919	76	..	-	34	9	22	-	20	-	21	-	6.3	31500	-	-	-			-	1	1	-	1	3
920	156	-	-	31	8	53	1	51	-	38	1	5.6	27400	-	13		4.2	77		3	3	8	2	3
921	72	-		40	13	22	-	20	-	15	-	5.2	17100	-	4	...	...	...	-	4	4	2	1	-
922	96	-		27	17	42	2	35	-	20	1	5.3	18900	-	16		3.5	62	-	7	2	9	3	-
923	13	-		54	-	3	...	...	...	...	...	...	...	-	...	...	...	...	-	...	...	...	...	...
924	9		-	-	11	4	...	...	...	...	...	...	...	-	...	...	...	...	-	...	...	...	...	...
925	19	-		26	5	6	2	5	-	1	...	...	...	-	4	...	...	...	-	2	1	-	-	-
926	20	-		25	5	6	-	6	-	3	...	...	...	-	3	...	...	...	-	-	-	-	1	-
927	55	11	-	53	9	13	2	13	-	10	1	6.1	31900	10	3	...	...	...	...	3	3	1	-	1
928	38		-	34	16	11	-	11	-	8		6.8	...	-	2	...	...	...		1	1	1	1	-
929	59	-		46	2	13	-	13		13		6.8	44200	-	-		-	-		1	1	1	-	-
930	36	8		33	6	13	-	13	-	10	-	5.6	23400	10	2	...	...	...	...	1	1	2	1	-
931	32		-	34	3	8	-	8		5	-	6.0	...	-	3	...	...	...	-	1	1	-	1	-
932	65			46	2	19	2	19	-	14	-	5.4	28000	-	3	...	...	...		1	1	3	1	-
934	49	-		41	14	13	-	13		9	-	6.1	31400		4	...	...	...	-			-	1	-
935	74			34	3	24	-	24		12	-	6.4	27300		11	-	4.7	103		3	3	3	1	1
56	7274	-	3	32	14	2461	28	1720	120	1607	7	5.1	15700		809	13	4.3	96	-	168	168	416	176	52
101	30		-	33	17	9	-	9		5	-	5.4	27600		4	...	...	...		1	1	1		-
102	46	-	-	41	9	11	1	11		5		6.6	15000	-	5	-	5.2	79		4	4	2	1	
103	79	-		30	6	28	-	28		13	-	4.9	11600		15	-	3.8	63		3	3	4	2	-
104	53			34	2	14	-	14		10		5.7	13500		4	...	...	...		1	1	1	-	-
105	94		-	37	2	24	-	24	-	16		5.4	13000		8		5.0	99		4	4	1	3	-
106	19			16	21	10	1	8	-	6	-	5.0	15300		3	...	...	...			-	3	-	1
107	13			15	46	7	-	7	-	5		6.8	18000		7	...	...	...	-	-		3		-
108	11		-	9	46	4	...	..	...	...	...	..	...		...	...	...	...	-	..	...	...	...	...
109	3	...	...	...	...	1	...	...	...	...	...	...	...	-	...	...	...	...	...	...	...	...	...	...

Figure A-1. Typical Page of Block Statistics

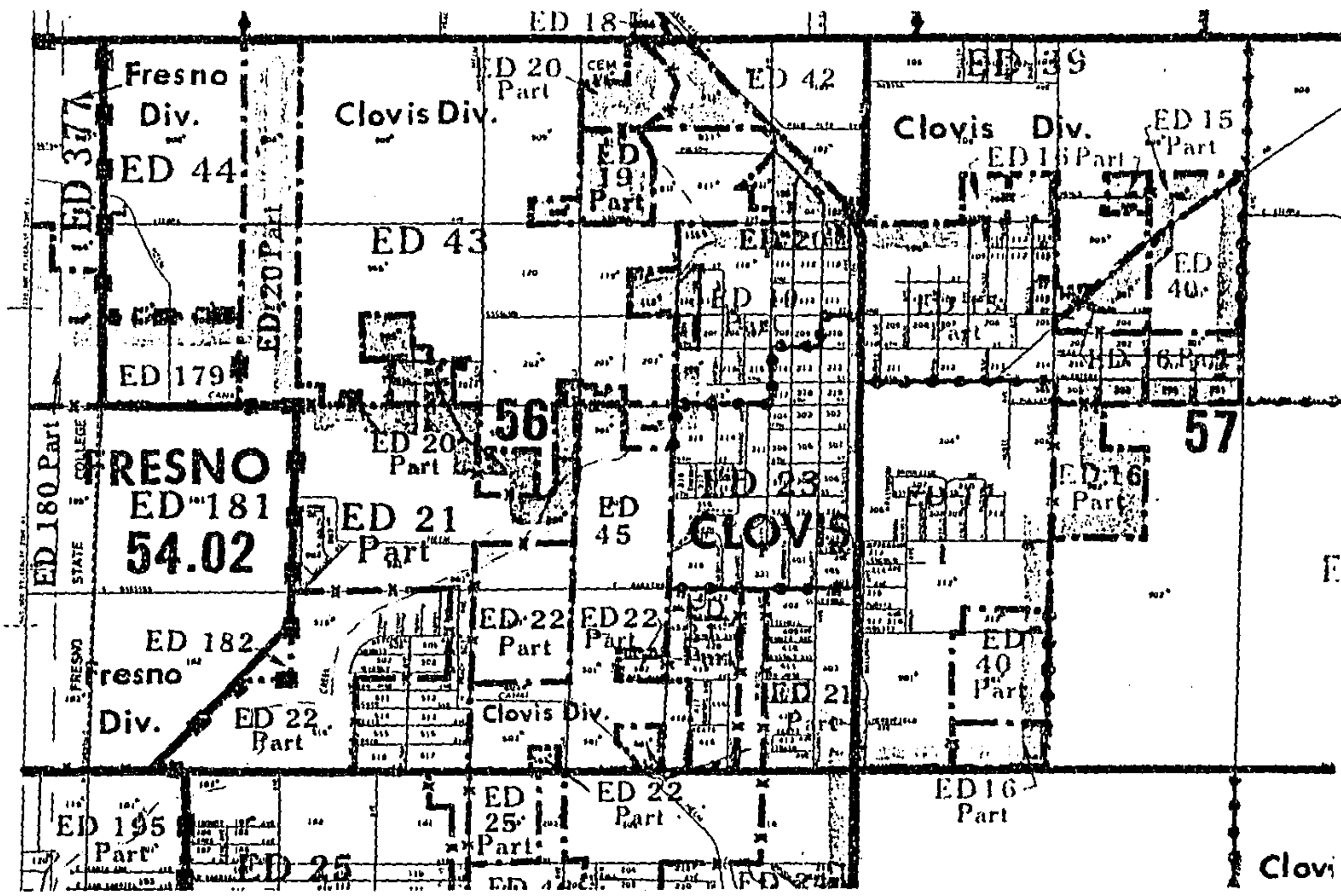


Figure A-2. Typical Census Map

These materials were used to randomly select appropriate numbers of census tracts and blocks within each selected urbanized area.

In the first year, this was done on a zone-by-zone basis. For each urban zone in which sites were to be located, tracts were from the set of tracts contained in that zone. Next, for each selected tract, a block was randomly selected from the set of blocks which compose that tract.

In the second year, tracts were selected from the urbanized area as a whole, with the random selection process weighted for population in the same manner as the second year urbanized area selection process. Tracts were selected until each urban zone had a sufficient number of tracts. Extra tracts which were obtained in this process were used as alternates. Blocks were then selected from each tract, again on a population-weighted basis.

Alternate census tracts and blocks were selected in both years for use in the event that certain blocks were unacceptable for monitoring. This would be the case if: (1) the block fell within an Ldn 65 contour around an airport; (2) the block contained no inhabited residential units, or was otherwise significantly altered during the period between 1970 and the time of the study; (3) the block was located in an area judged too unsafe for measurement activity; or (4) no residential units on the block were made available for monitoring by their occupants.

Once the census tracts and blocks were selected, they were randomly designated as high- or low-traffic impact according to the number of sites needed in the particular urban zone in the particular traffic impact category. These designations were adjusted in the cases where the block had no available residential units in its designated category.

A-2-4 Selecting Residential Units

The selection of residential units from the selected blocks was made by the monitoring field team, usually just before initiation of measurement activity at the selected site.

The first step was to identify the residential units on the selected block which fell into the traffic impact category for which the block was designated. This was done by counting mailboxes or doorbells.

Next a residential unit was randomly selected from the set of identified units by use of a random number table. Permission to conduct noise measurements at the selected unit was then sought. If permission was not obtained, permission to monitor an adjacent unit was requested. This process continued until a measurement site was obtained.

The selection of residential units for measurement sites was one of the more difficult activities in the survey. Field personnel had to make judgments regarding the safety of the area and its conformity to the 1970 census maps, as well as be prepared to encounter the diverse reactions which a stranger asking permission to measure noise levels on the front yard has every reason to expect. A discussion of the field experience of selecting residential units is given in appendix B.

A-3 MEASUREMENT PROTOCOL

The measurement protocol used in the survey was typically carried out over a 24-hour period. It consisted of two elements, continuous noise monitoring and microsamples.

A-3-1 Scheduling

The measurement protocol was usually begun immediately after the measurement site had been obtained. No formal scheduling procedures were followed in selecting a day on which to obtain and monitor a particular site. Rather, this was determined by the travel schedules of the field measurement teams and the geographical layout of selected census tracts and blocks. It was anticipated that this would result in a set of measurement days which was aggregately representative with respect to such variables as weather, holidays, and day of the week. Of course, the results at any particular site are likely to be somewhat less representative.

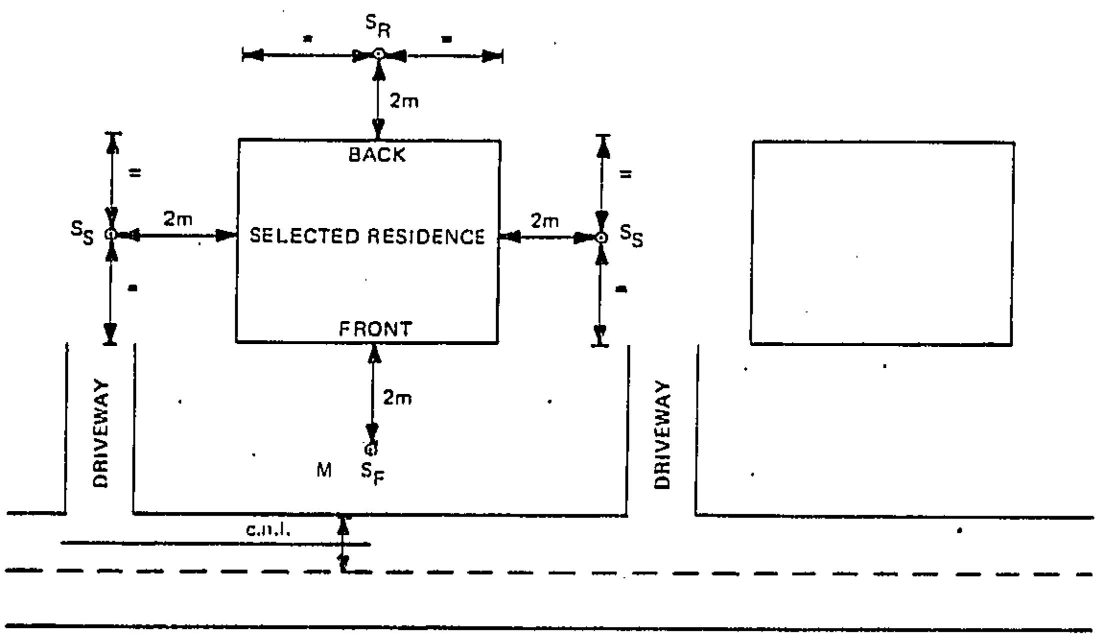
A-3-2 Continuous Monitoring

The continuous monitoring was usually conducted for a 24-hour period. The measurement apparatus consisted of a microphone and an automated sound level recorder. The apparatus are described in detail in appendix C.

The microphone was located at the architectural front of the residential unit, and the recorder placed in a secure location near it. In the case of single family homes, the microphone position was specified at 1.2 m above the ground, 2 m out from the front of the building, and 2 m from the corner of the house farthest from the driveway. In the case of houses with no driveways or with driveways on both sides, the microphone was placed equidistant between the sides of the house. This location is illustrated in figure A-3.

For residential units in apartment buildings, the microphone was placed at the same height as the selected residential unit, 2 m from the front of the unit, on a convenient balcony or other outside location.

After the continuous-measurement system was set up at the specified location, it was calibrated and the recorder system started. The system was inspected during each subsequent visit to the site, and was recalibrated at the end of the measurement period.



⊕ =MICROPHONE LOCATION

M = CONTINUOUS MEASUREMENTS

S_F, S_S, S_R, = FRONT, SIDE, AND REAR SATELLITE MEASUREMENTS

Figure A-3. Measurement Locations Used in the Survey

The continuous monitoring was extended to 5 days at eight of the measurement sites. This required no changes in the measurement procedure.

A-3-3 Microsamples

Microsamples were collected manually over 30-minute periods at accessible sides of the residential units. The microsamples were usually obtained in sets of two, one at the front of the unit and one at another side. Three such sets were usually collected, one each in the daytime (0700-1900), evening (1900-2200), and nighttime (2200-0700). Scheduling within this framework was based primarily on logistical considerations.

The microphone location for these measurements was 2 m outside the midpoint of each exterior wall, and 1.2 m above the ground. Figure A-3 illustrates these locations. Satellites were omitted when the distance between a wall and another building was less than 3 m.

Each microsample consisted of about 120 sound-level measurements and source identifications, made once every 15 seconds. The sound-level meter was set to "slow response," and was calibrated before and after each microsample. A sample microsample data sheet is shown in figure A-4.

A-4 ANALYTICAL PROCEDURES

A-4-1 Continuous Monitoring

Sound levels measured in the continuous-monitoring procedure were encoded on digital tape. The tapes were analyzed by means of a digital translator interfaced with a computer, as described in appendix C. Computer output consisted of hourly equivalent sound levels and statistical levels; the daytime, nighttime, and 24-hour equivalent sound levels; and the day/night sound level (Ldn). These data were stored in a Statistical Analysis System (SAS) data base.

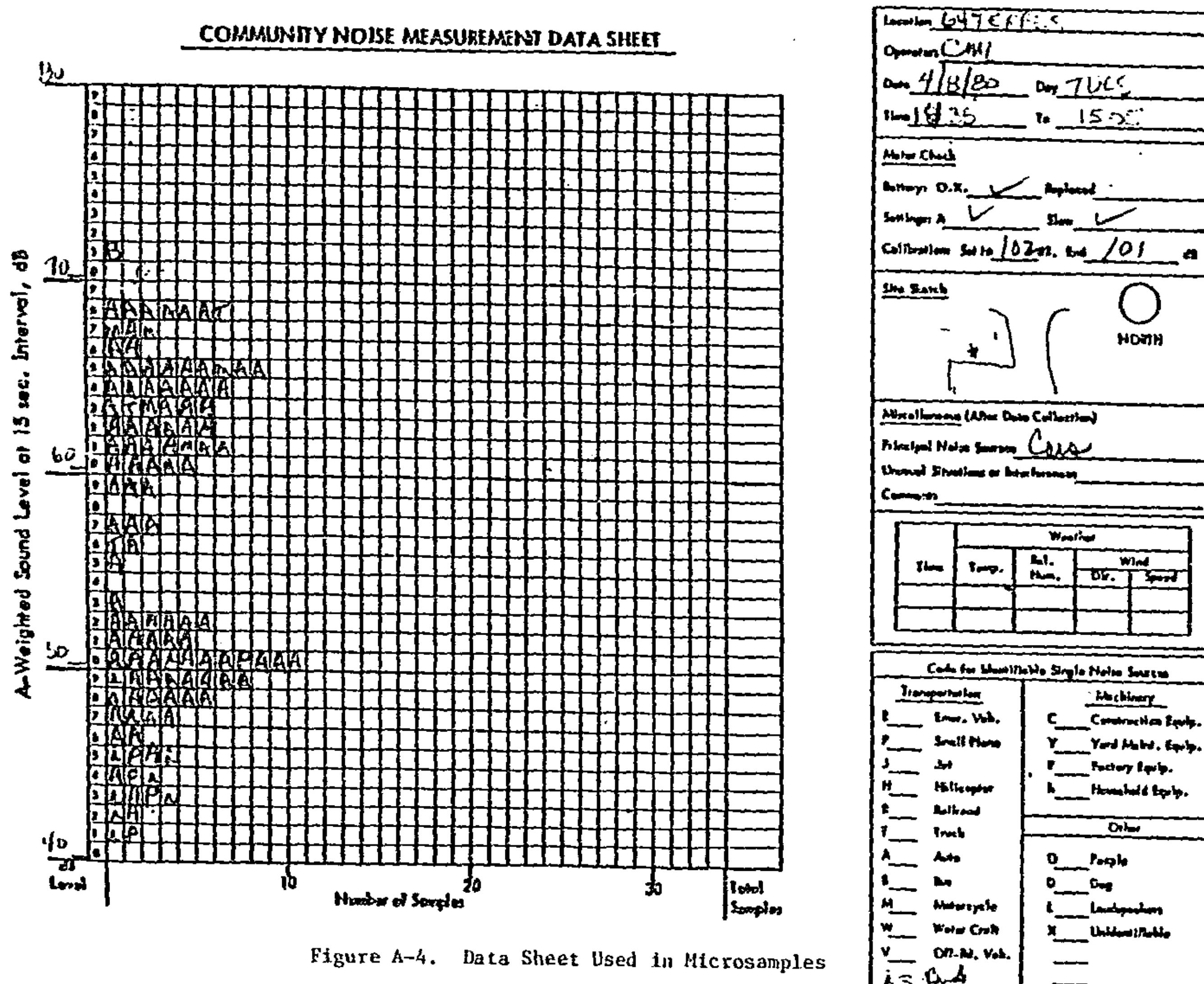


Figure A-4. Data Sheet Used in Microsamples

A-4-2 Microsample Data

Each microsample was reduced to find:

a. the equivalent sound level as averaged over the entire set of measurements taken in the microsample;

b. the frequency of identification of each source type; and

c. the equivalent sound level of each source type as averaged over the set of measurements in which it was identified.

These data, along with the time of day and the designation of the side of the unit at which the microsample was collected, were stored in a SAS data base.

A-4-3 Other Data

In addition to the acoustical data, the urban area size, urban zone density, and traffic impact categories were stored in a SAS data base. Also included were the actual urbanized area population and urban zone density of each site, based on the 1970 census. These data were used in developing cell-by-cell profiles and for factor analysis.

APPENDIX B
FIELD EXPERIENCE AND SURVEY CRITIQUE

B-1 INTRODUCTION

The site selection and measurement protocols described in chapter 3 and appendix A are based upon the Environmental Protection Agency (EPA) and contractor experience in community noise assessment. Essentially, these protocols are scaled-up versions of similar procedures which were developed for local application. Although such adaptations are quite straightforward, their practicability and utility can be ascertained only through implementation. To provide useful input for future studies, as well as to allow a more informed assessment of the results of this study, some remarks on this experience are required.

B-2 SITE SELECTION

The most difficult part of the methodology was the site selection. Several features of the study contributed to this difficulty:

a. The field engineers were usually in unfamiliar territory, making it more difficult to find preselected census tracts and blocks.

b. The limited travel budget and tight schedule usually allowed only one visit to the selected block for the purposes of site selection.

c. The random block selection process resulted in a number of unsafe or otherwise unusable blocks being selected.

d. The survey required permission from residents before a measurement site could be established.

The above circumstances resulted in the loss of some measurement sites, and in the relocation of others. The lost sites were the direct result of the limited travel budget and the tight measurement schedule. The length of stay in each urban area was predetermined by this schedule, which was generally adhered to even if the desired number of sites had not been obtained. Relocation of measurement sites occurred at both the block and residential unit level. Block relocation occurred 19 times. In nine of these cases, the original block was judged too unsafe to enter or leave measurement equipment in. In other cases, the entire block fell within an Ldn = 65 dB contour around an airport (three times), the block had been changed into an exclusively nonresidential area (three times), or permission to measure could not be obtained at any residential unit on the block (three times). Finally, in the Buffalo urbanized area, a selected block was condemned because of the Love Canal toxic waste dump site.

When blocks had to be reselected, two different procedures were used depending upon the circumstances. In cases where the problems causing reselection were confined to one particular block, a block adjacent to the initially chosen one was selected randomly. In cases where reselection problems concerned a larger area, a new block was selected randomly from a set of blocks not included in the area. In some cases, selection of a new census tract was required also.

Residential unit relocation was much more common than block relocation. By far the most prevalent cause for this factor was failure to obtain permission to conduct measurements at the residential unit that had been selected initially. The lack of permission was generally due to no one being at home when the unit was called upon. In other cases, permission was refused or could not be granted as a result of a neighborhood association or other cooperative living arrangement. In all, about 40 percent of the initially selected residential units could not be used for these reasons. Of the cases described, 40 percent resulted from no one being at home, 50 percent involved a refusal or inability to grant permission on the part of the occupants, and the remainder were the result of safety considerations.

Selection of alternate residential units was accomplished deterministically on the basis of the initial residential unit selection. The residential units on the selected block had been assigned numbers in the initial selection process. If the nth unit had been selected initially and could not be used, the unit numbered n+1 was then selected, followed by n-1, n+2, n-2, etc. Thus, the unit used for the measurement site was always the one nearest to the initial selection, which was located on the same block and at which permission to monitor could be obtained. In only nine cases was this unit more than two units distant from the initially selected one.

Apartment units and other multiunit complexes posed the greatest problems in the residential unit selection process. For example, measurements made above the first story required entrance into the residential unit by the field engineers, and this made obtainment of permission from the occupants substantially more difficult. Another contributing factor in some cases was the lack of authority of occupants to grant permission. No time had been allocated for contacting landlords or meeting with residents' associations to obtain this permission, and only a limited attempt could be made to do so in these cases.

Of the 11 instances in which the randomly selected unit was part of a large apartment building or multiunit complex, the selected unit was successfully used three times. In two cases, the unit was relocated to a first-floor residential unit in the same building. In six cases, an alternate site outside of the apartment building or multiunit complex was used.

In three of the six alternate sites, the site used was a public building adjacent to or across the street from the original selection. The use of such a building allowed a measurement location at the same height as the initially selected one, and was considered preferable to relocating to a less similar residential unit.

The necessity for selecting alternate residential units and blocks during the survey introduces the possibility of biased results. The three most likely sources of bias are:

a. Relocation of sites out of dangerous neighborhoods.

b. Relocation of sites to residential units where the occupants were at home at the time of the site visit.

c. Relocation of sites to residential units from multiunit complexes, and especially from upper story units in these complexes, to units outside of the complexes.

The relocation procedures described in a through c above result in a sample of residential units which:

a. Underrepresents areas that appear unsafe.

b. Overrepresents residential units that are occupied during the daytime hours (during which site selection generally took place).

c. Underrepresents residential units located in multiunit complexes, and especially those located above the first story in these complexes.

While it is desirable to avoid such biases, their expected effect on the survey results is minimal. None of the circumstances that gave rise to the biases occurred very often, and it is doubtful that any substantial correlations exist between noise environments and the affected variables.

One possible exception to this is the underrepresentation of non-first-story residential units. A systematic approach to avoiding this bias is recommended for future studies of this kind.

B-3 MEASUREMENT PROTOCOL

The basic measurement procedures that were included in the measurement protocol are 24-hour continuous noise monitoring and 30-minute microsamples. While both of these procedures have been used extensively in local surveys, some problems arose in their implementation for the National Ambient Noise Survey. These problems resulted from:

a. The statistical nature of the survey.

b. The tight measurement schedule.

c. The diversity of residential units being used as measurement sites.

d. The application of noise assessment techniques to noise-free environments.

The above features of the survey led to three areas of difficulty: (1) choosing measurement positions, (2) minimizing the impact of the field personnel on the noise environments being studied, and (3) identifying sources observed during the survey.

The measurement positions were specified in the measurement protocol, and were defined relative to the outer facades of the residential units. These specifications were necessary to obtain comparable data for each site without performing time-consuming preliminary measurements. The specified positions were found to be satisfactory about 90 percent of the time. Of the 10 percent of the exceptional cases, the most frequent problem resulted from obstructions such as trees and bushes or from the presence of a walkway that could not be obstructed. In such cases, the measurement positions were simply moved laterally to the nearest suitable location.

In three cases, the location was found to be unsuitable as a result of acoustical considerations. This occurred when the specified position was extremely close to an operating air-conditioner or a window that was transmitting a high volume of noise from the residential interior. Because the objective of the survey was to study noise from exterior sources, the use of these specified positions would have produced distorted results, and a lateral adjustment of the measurement position was made to avoid this outcome.

While the infrequency of this circumstance minimizes its significance, the importance of the field engineer's judgment in making these adjustments must be realized. There is a basic conflict between the need to perform these measurements where they will most accurately reflect the noise impinging upon the building facade and the need to avoid noise emanating from that facade. Future protocols should address this conflict, and allow field personnel some flexibility in dealing with it.

The problem of survey personnel impacting the noise environments being studied occurred when either the survey personnel generated the noise or when they acted as a stimulus for others to do so. In some areas, the noise of the field team's motor vehicle coming to and leaving the site was a noticeable acoustical event. This was especially a problem during the late night measurements. In other cases, the presence of the field team aroused either human or canine curiosity and, with that, either talking or barking.

In all of these cases, only the 24-hour measurement was impacted. From the point of view of this single measurement, the visits to the site to collect microsamples might have been better avoided. In any case, a cost-benefit analysis of these visits should be undertaken in the development of future protocols.

The source identifications used in the microsample procedure were the third source of difficulty. Problems arose when predominant sources could not be seen, or when there was no obvious predominant source.

Cases in which predominant sources could not be seen occurred most frequently when a solitary vehicle on an unseen roadway was the predominant source. In some cases, the type of vehicle could be surmised on the basis of hearing alone, but more often the source was recorded as "unidentified traffic." Thus, both aggregate traffic noise and unseen solitary vehicle noise are included under this designation.

Cases in which there was no obvious predominant source occurred when natural sounds, such as wind, birds, and crickets, and distant man-made sources (usually distant traffic) were both present in the acoustic environment. If the natural sound was distinct (i.e., produced a deflection of 3 dB or more on the sound level meter) the source was identified as the natural source. If the natural sound was indistinct but had a masking effect on the man-made noise (i.e., produced a deflection of 1 to 2 dB) the source was identified as residual. If the natural sound was detectable but produced no deflection in the meter, the man-made noise was identified as predominant.

These rules of thumb evolved over the course of the survey, and arose from the attempt to use microsampling in situations for which the procedure was not really intended. In the future, careful consideration should be given to the utility of performing microsampling in environments that include only low-level sources. Microsampling is best considered as a diagnostic procedure that is most useful when one or more high-level sources are present. When only low-level sources are present, the reliability of the procedure is greatly diminished.

B-4 LOGISTICS AND SCHEDULING

Reference has been made to the severe time constraints under which the survey was performed. The efficient use of time and the careful planning of travel were critical to the success of the survey. It was found that such efficiencies allowed the field team to make two complete sets of measurements per day.

The most time-consuming element of the survey was travel between cities. The large volume of measurement equipment made driving the only practical mode of transportation, although flying would obviously have been faster. The survey was scheduled to minimize the necessary intracity travel, and this efficiency was increased somewhat during the second year by the greater number of urbanized areas and sites being visited.

Intercity travel time to sites varied greatly but generally was between 45 and 90 minutes. Attempts were made to minimize the travel time between two sites that were being measured at the same time or consecutively. The larger urbanized areas include substantial amounts of land area, making such planning especially important.

Implementing the protocol itself was much less time-consuming. Securing a measurement site usually took about 15 minutes, and each visit to the site lasted about 45 minutes.

The field team found that performing two sets of measurements daily was possible yet extremely taxing. Certainly this represents the upper limit of measurement activity which can be reasonably expected of a two-person team. Moreover, occasional slippages in schedule are bound to occur when the two-site-per-day regimen is followed.

B-5 CONCLUSIONS

As a pilot study intended to provide a statistically valid profile of residential noise environments across the United States, the National Ambient Noise Survey was an overall success. The survey methodology can serve as a basic framework for future surveys at either the national or subnational level. The survey results represent the first statistically valid national profile of urban residential noise environments ever assembled.

The problems with methodology that are most in need of consideration are (1) the treatment of multiunit residential complexes, (2) the method of specifying microphone locations, (3) the tendency of field personnel to impact the acoustical environment being measured, and (4) the use of microsampling when only low-level sources are present. Further consideration may lead to solutions of these problems, or may reveal that, given resource constraints, the approaches used in the survey are the best available. In either case, a survey such as this one must always represent compromises between what is desired and what is possible. So long as the terms of these compromises are understood, the resulting data can be interpreted in a correct and meaningful way.

Although the methodology used was developed especially for this national survey, its applicability extends to surveys on any other scale: community, regional, or statewide. Such application is certainly desirable, for it is at these other jurisdictional levels that most noise control policy is made. It is recommended, however, that these applications be carefully considered as to their purpose and the obvious logistical advantages that localized survey programs have over national ones. While the benefits, on an informational level, of conducting local surveys analagous to the National Ambient Noise Survey are obvious, no such benefits accrue from rigorous adherence to all aspects of that survey's methodology. Many of the problems encountered in the National survey may be avoided altogether in local surveys if this point is remembered.

APPENDIX C

24-HOUR CONTINUOUS MEASUREMENT AND ANALYSIS PROCEDURES

C-1 INSTRUMENTATION

Acoustic instrumentation utilized for community noise surveys which employ continuous statistical monitoring is available in a number of different formats and with varying capabilities. Three main categories exist and these include:

a. Equipment designed to hold the data internally in software storage in the field, and relinquish same upon command at the end of the 24-hour sampling.

b. Equipment that must be monitored periodically during the 24-hour period to determine hourly, or shorter-duration, statistical information.

c. Equipment designed to encode the data on tape (either magnetically or on paper) in the field for later decoding in the laboratory.

Each of the above equipment types has its inherent advantages and disadvantages. In general it has been found useful to back up 24-hour samplings with periodic manually sampled checks of the "real time" noise values. Portable sound-level meters placed in proximity to the stationary 24-hour microphone are used for this type of monitoring. This procedure was part of the National Ambient Noise Survey measurement protocol and was followed rigorously throughout the survey. Three half-hour samples, one each during daytime, evening, and late night, were performed adjacent to the stationary continuous 24-hour monitoring equipment. It was determined from comparisons of these satellite half-hour samplings with the same digitally instrumented sampled data, that the statistical parameters were within 2 to 3 dBA.

Twenty-four-hour statistical sampling instrumentation utilized for the survey consisted of a Bruel and Kjaer (B&K) Model 181 digital data logger, Model 182 digital data translator, Dec-interface, and Digital Dynamics model PDP 11/45 computer with Dec printer and 9-track tape reader. The general format of this system is in Fortran IV with 20- to 30-minute turnover time per 24-hour survey.

The B&K 4161 1-inch microphone and 2619 preamplifier units at the front end of the 181 system meet American National Standards Institute (ANSI) S1.7-1971 Type I specifications and the placement of the microphone/tripod combination was in substantial conformity to ANSI S1.13-1970, Field Method techniques. The 181 data logger digitization rate was preset to A-weighting and a 0.5-second sampling period for all but the 5-day surveys, in which a 1.5-second sampling was achieved.

The field implementation of this system for real-time gathering of 24-hour data is given below.

C-2 ENCODING PROCEDURE

a. An Information Terminal Certified Digital cassette* was mounted into the drive system of the 181 system. The tape was advanced forward beyond the clear leader to the beginning of the ferric oxide backing.

*All cassettes were bulk-erased prior to the survey to insure a clean encoded word stream.

b. The 181 system was energized and allowed to stabilize for 15 minutes prior to calibration. A B&K Model 4230 1000-Hz calibrator was used to calibrate the system. Prior to calibration internal system noise was measured by isolating the microphone with a Model 4220 Pistonphone coupler and recording the output onto a B&K Model 2306 graphic level recorder.

c. Calibration commenced by engaging the 181 drive system and loading forward the tape to the point of digitization. The calibrator was placed over the microphone and held in the ON position for 30 seconds. The microphone/tripod system was already in-situ for the site analysis.

d. The calibrator was carefully removed and replaced with a 1-inch windscreen. The 181 system was sealed, covered with a weather-proof cover, and carefully placed behind bushes or shrubs in proximity to the source house.

e. At completion of each 24-hour survey the calibration procedure was repeated and the tape removed. The tape was either mailed or handcarried back to the computer laboratory for decoding and processing.

C-3 DECODING PROCEDURE

a. The 181 encoded digital tape was placed in the 182 digital translater unit located in the PDP 11/45 main frame room. An input name was assigned to each cassette. This name appeared as output file titles at the top of the statistical printout sheets for each site. Total decoding time for each digital tape was 18 minutes.

b. The digital tape output was transferred to disk storage for processing. The processing time for the output printing was 6 minutes.

c. The output files were retained on 9-track tape storage, with retrieval time approximately 3 minutes, including printing.

C-4 OUTPUT

The output of statistical data sheets provide the following information:

a. Number of samples taken per 15-minute, hourly, 24-hour, daytime, and nighttime sampling periods.

b. The percentage of time A-Weighted noise levels were exceeded for 1 percent, 10 percent, 50 percent, 90 percent and 99 percent (L1, L10, L50, L90, L99) of the measurement period (15-minute, hourly, 24-hour, etc.).

c. The standard deviation (σ) for each measurement period.

d. The mean A-Weighted level for each measurement period.

e. The equivalent A-Weighted sound pressure level (Leq) for each measurement period.

The above parameters are formatted for each 15-minute as well as hourly period. Four sheets of data output were provided per site. The fourth sheet included summary information for the following statistical data:

a. L1, L10, L50, L90, L99 percentile units for daytime (7 a.m. - 10 p.m.), nighttime (10 p.m. - 7 a.m.), and 24 hours.

b. Equivalent sound pressure level for daytime, nighttime, 24 hours.

c. Mean standard deviation over 24 hours.

d. The day-night sound level (Ldn) for the survey.

C-5 MULTIPLE-DAY SITES

The encoding/decoding procedures were utilized for the multiple-day surveys, with the only difference being the use of a 1.5-second sampling rate for five of the eight sites. This required hand calculation of the daytime, nighttime, and 24-hour statistical parameters in each instance. The sampling rate was increased so as to disturb the environment as little as possible by supplying the 181 system with a tape and sample rate configuration requiring only one recalibration per 5 to 6 days of sampling. In retrospect a change of tapes once a day (allowing for the normal 0.5-second sampling) would have been preferable.

C-6 EXTRANEOUS FACTORS

Ninety-four of the 128 survey tapes encoded in the field were decoded with no extraneous errors or modification. In 30 of the remaining 34 surveys, minor editing corrections were required for a variety of reasons, but in no way were the results affected to an extent beyond the inherent inaccuracy of the measurement system (±0.5 dB fast response). Some of the reasons for modification of digital tape results included the following phenomena:

a. Dropout errors in the digital tape.

b. Rain or extraneous wind or moisture conditions occurring randomly during the 24 hours of sampling.

c. Events precipitated by the presence of the satellite data sampling at the survey site. These could include dog barking, curious onlookers, children playing around the microphone, extra horn honks, accidental bumping of the 24-hour microphone, noise caused by setup of satellite measuring equipment, etc.

d. Minor encoding errors caused by harsh environmental conditions (overheated or excessively cold) and general wear and tear of instrumentation utilized 7 days a week, 24 hours a day for nearly 5 months of continuous monitoring. The major problem in this instance was the 181 unit tape drive malfunction due to the need for internal lubrication. Four of the remaining 34 surveys required modifications due to this type of error. This included extensive digital review of the original cassette tape. Detailed procedures for the modifications discussed above are presented below.

C-7 EDITING AND CORRECTION PROCESSING - DIGITAL DATA CASSETTES

As might be expected from any statistical data gathering instrumentation, hardware-generated encoding errors often occur in the field and most systems provide for correction either at the front end of the system or during decoding. The field measurement methodology provided for absolute calibration at the front end of each tape, encoded with the corresponding "word code" for 94 dB. Utilizing this number as a reference, all other sound pressure level values, as encoded every 0.5 second, were assigned corresponding word values. Encoding errors always appeared as words with values that could not possibly represent actual noise levels. This is to say that the octal* word error would be encoded as 1002_8 or 423_8 which translated with the corrected base value (usually 31-34 dBA) would come out 543 dBA or 327 dBA, an obvious data error. The reasons for encoding errors such as the above could include:

a. Dropouts in the digital cassette.

b. Someone hitting the measurement microphone.

c. Someone shouting into the microphone.

d. Moisture condensation on the microphone.

e. Mechanical drive system discontinuities in the 181 system unit.

f. Arcing in the preamplifier.

*The PDP 11/45 System uses octal number system.

In cases where the drive system actually backed up on itself for a momentary half-second sample, two words could go down on tape where one word belonged, thus effectively doubling the total numerical value. What would be translated as 64 dBA could actually be encoded as 128 dBA. Such is one pitfall of word encoding of digital values. In instances where very hot or humid conditions prevailed the drive system could actually speed up as much as 25 percent due to crystal oscillator control malfunctions.

Error correction for these phenomena took place in both the encoding and decoding instrumentation process.

In the field unit, the following error correction techniques were utilized.

a. Minute/hour markers.

b. Drop-out compensator.

c. Anti-aliaser.

The decoding error correction capabilities are more extensive since the computer software capability is essentially limited only by word space. For the PDP-11/45, over 130,000 storage blocks (256 words per block) are available per disk storage unit. For digital cassettes recorded in the field on the National Noise Assessment, decoding error correction consisted of the following:

a. The B&K decoding unit contains an 80-dB dynamic range cutoff switch that, when activated, will automatically truncate data words above an 80-dB base level input. Thus, no more than a nominal 120-dB peak level will be passed to the digital surface, eliminating real-time information above such level.

b. In instances in which dropout errors or word-over-word encoding errors occur, a special software routine was written to search for such discrepancies. In this instance any word (noise level) encoded above a certain preset decibel level is replaced with the previous word value. Thus, if the level is set at 100 dB, any word written in excess of 100 dB will be replaced with the previous value. This is actually a software version of the error correction technique previously described, with the added advantage of smoothing the time domain contour with previously encoded real-time data. This technique allows the removal of such extraneous events as children yelling into the microphone, dog barking caused by the satellite analysis team's presence in the environment, arcing in the microphone due to excess moisture or dewpoint conditions, and sundry disturbances of the 24-hour setup. It should be noted that such extraneous data appears as abnormally encoded data on the decoded computer printout and is readily identifiable as such.

c. The previously mentioned decoding errors due to digitization failure or mechanical drive failure show up in decoding as extraneous word codes in the output. These are automatically printed as sample errors under the sampling rate column in the decoded output files for each cassette survey tape. These numbers are easily corrected by the edit routine by simply running a special software program that accepts only numbers less than 110 dB and prints out the real-time sampled levels as if the doubling or duplication of words never occurred.

d. The last editing program available was utilized for surveys on which the drive system and attendant control-crystal malfunction caused less than 24 hours of data to be encoded on the input cassette tape. It should be noted that this type of error occurred in less than 10 percent of the survey. The correction consisted of spreading the less-than-full-day sample out to 24 hours, realizing a full-day sampling, and comparing satellite-sampled 1/2-hour readings with the finished edited 24-hour sample to determine correlations and differences. The theory behind this editing procedure is that random malfunctions throughout a particular 24-hour day occur in an even distribution, making the corrected sample correspond evenly to the real-time noise events presented to the measuring microphone. Data reduced utilizing this procedure indicated that the theory, as applied to the cassettes so edited, fit the normal distribution of given values within the sample error of the survey format.

A formal breakdown of the data encoded for 24-hour surveys indicated the following:

a. Four surveys edited for less than 24 hours of data.

b. Twenty-six surveys edited for minor encoding errors caused by yelling into microphones, moisture, and other extraneous phenomena.

c. Ninety-seven surveys decoded with no error correction required.

APPENDIX D

RESULTS SUPPLEMENT

D-1 INTRODUCTION

The results presented in chapter 4 are based upon statistical analyses of "raw" acoustical data obtained in the field. To appraise the results critically, it is necessary to consider both the quality of the data obtained, and the analytical procedures which were performed on that data.

D-2 QUALITY OF DATA OBTAINED

D-2-1 Continuous Measurements

The accuracy of continuous sound level measurement is largely determined by the sampling rate employed. This rate was 2 samples per second (sps) for the 24-hour monitoring and 0.66 sps for the 5-day monitoring.

EPA has found that sampling rates in excess of 0.4 sps can be expected to generate Leq measurements within 0.5 dB of the true value. Sampling errors in the continuous measurements are thus not significant sources of error to the survey results.

D-2-2 30-Minute Microsamples

EPA has found the 30-minute microsamples to yield estimates of the Leq accurate to within 3 dB when roadway traffic is the predominant noise source. Further discussion of this error is included in paragraph D-3-2.

Estimates of the errors in source contribution data developed from these microsamples are difficult. Among the sources of error are:

- o errors in source identifications
- o sampling errors
- o contributions of non-predominant sources to noise levels

It is not possible to quantify the errors resulting from mistaken source identifications. Consideration of this phenomena would require a study involving the simultaneous collection of microsamples by different observers. A small scale study of this sort is highly recommended to those who make extensive use of this procedure.

Sampling errors affect both frequency and Leq(id) estimates. In the case of frequency, the situation is best approximated by a binomial distribution, where a trial is considered a single source identification, and a success the identification of a particular source. Thus each satellite consists of 120 trials, subsets of which are successful trials for each source identified in the microsample.

Using this model, the expected error in frequency is given by

$$\Delta Fi = \sqrt{120\ Fi(1-Fi)}/120$$

where Fi is the frequency of source type i as obtained from the microsample. Thus a frequency of .01 percent has an estimated error of .01, a frequency of .1 has an error of .03, and a frequency of .5 has an error of about .05.

The error associated with Leq(id) values also depends on the number of times the source was identified, as this also determines the number of measurements. The error is given by the equation

$$\Delta Leq(id) = \sigma i / \sqrt{120 x Fi}$$

where σi is the standard deviation in noise levels associated with the ith source, and Fi is the frequency of identification of that source. The value for σi is source dependent, ranging from 0 for steady state source to as high as six or seven for trucks and buses.

Leq(id) values for these latter sources are also strongly effected by the presence of competing sources. Such competing sources tend to drown out low level sources. Therefore, a source is most likely to be heard when it is emitting high noise levels, thus biasing upward the sample of sound level measurements upon which the Leq(id) value is based.

Contributions from unidentified sources also result in an upward bias of this sample. If these sources combine to account for half the sound energy at the time of a measurement, then the noise level associated with the identified source is 3 dB more than the actual level of that source. A 2-dB error would result if such sources accounted for 40 percent of the energy, and 1-dB error if they accounted for 20 percent of the energy. While it is reasonable to expect that most situations encountered fell somewhere within this range, a more precise treatment of this source of error is not possible.

D-3 ANALYTICAL PROCEDURES USED

D-3-1 Distribution of Population over Ldn

The basic problem in obtaining this distribution was to translate measurement results from 12 subpopulations (the sampling cells) into results pertaining to the aggregated urban population.

To obtain the raw distribution, the distributions obtained for each sampling cell were combined by means of a weighting scheme which took into account the human populations of the individual cells. Thus, if 20 percent of the Ldn measurements obtained in a particular cell were between 60 and 61 dB, and if that cell had a population of 10 million, then 2 million of that population was assumed to be exposed to Ldn between 60 and 61 dB. Summing of these individual cell distributions produced the overall distribution.

To obtain the normal distribution, the individual cell results were used to generate estimates of the mean Ldn and the standard deviation in Ldn. The mean was obtained using the equation

$$\bar{\mu} = \sum_{i=1}^{12} Pi \times \bar{X}i,$$

where Pi is the fraction of the population in the ith sampling cell, and Xi is the mean of the Ldn measurements obtained in that cell. The standard deviation was obtained from the equation

$$\sigma = \left(\sum_{i=1}^{12} Pi(\sigma i^2 + (\bar{X}i - \bar{\mu})^2) \right)^{1/2},$$

where i is the standard deviation of the measurements obtained in the ith cell, and the other terms are defined as above.. A μ of 60.4 dB and a σ of 4.8 dB were obtained from these calculations. Together, these values define a normal curve, according to

$$P(X) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(X-\bar{\mu})^2/2\sigma^2},$$

where P(X) is the fraction of the urban population exposed to an Ldn of X. In all practical applications, this equation must be transformed to

$$P(X - \Delta X \leq X \leq X + \Delta X) = \frac{2}{\sigma\sqrt{2\pi}} e^{-(X-\mu)^2/2\sigma^2} \Delta X$$

where ΔX is a small but finite interval (1 dB, for example).

Use of these techniques assumes that the distribution is in fact normally distributed over Ldn. This is an untested assumption which would require a much larger sample size for adequate evaluation. The normal distribution is assumed because it is simple and has generally been found to be appropriate in this type of analysis, and because the raw distribution does not suggest any other standard distribution to be more appropriate.

D-3-2 Variation by Side

To obtain estimates on the variation in noise levels by side, microsample data was compared with data obtained at the continuous measurement site. Each 30 minute microsample consisted of 120 sound level measurements, and these measurements were used to obtain an estimate of the Leq over the 30 minute period. This Leq value was then compared with the Leq value obtained at the continuous measurement site for the hour in which the microsample was obtained. (Note that only half of this hour was covered by the microsample.) The differentials in Leq values were then averaged by side at which the microsample was obtained and by sampling cell. The results are shown in table D-1.

Clearly the weakest link in this procedure is the Leq obtained from the microsample. This is because of the sampling errors inherent in the microsample procedure, and because the microsample was obtained over only half of the time period considered in the continuous monitoring procedure. Some estimate of the resulting errors can be obtained by means of the differentials between the Leq values based on continuous monitoring and those obtained from microsamples at the front of the residential units. These microsamples were obtained at locations very near to the continuous monitoring site, thus the differentials obtained represent sampling errors instead of noise level variations. Inspection of table D-1 shows an average error of about 1.5 dB.

Note that, in 10 of the 12 sampling cells, the average Leq based on the front microsample is less than that obtained from continuous monitoring. This is the result not of faulty measurement equipment but of the nature of the averaging procedure. Leq is a logarithmic measure of sound energy, and it is the average energy obtained in the two measurement procedures which should be equal. Table D-1, on the other hand, reflects arithmetic averaging of the differences in sound level. If Leq(c) is the Leq obtained on the basis of

Table D-1. Average Differences in Noise Levels Between Microsample and Continuous Monitoring Results

Traffic Impact	Urban Area Size	Urban Zone Density	Front Delta	Side Delta	Rear Delta
High	Large	High	-1.2	3.7	8.2
High	Large	Medium-High	1.6	3.6	8.5
High	Medium-Small	High	3.1	3.4	6.9
High	Medium-Small	Medium-High	0.8	3.5	8.9
High	Medium-Small	Medium-Low	0.5	5.9	11.4
High	Medium-Small	Low	-0.4	5.4	14.7
Low	Large	High	1.9	1.2	1.9
Low	Large	Medium-High	1.1	3.9	3.0
Low	Medium-Small	High	1.7	3.1	6.6
Low	Medium-Small	Medium-High	3.1	4.7	6.0
Low	Medium-Small	Medium-Low	2.3	4.0	4.9
Low	Medium-Small	Low	-0.2	4.0	1.4

Delta - Average value of the quantity Leq(c) - Leq(m), where Leq(c) is the equivalent sound level as measured at the front of the residential unit by means of continuous monitoring, and Leq(m) is the equivalent sound level as measured at the front, rear, or side of the unit by means of a microsample.

continuous monitoring, and Leq(m) is that obtained on the basis of microsamples, then table D-1 reflects the value:

$$\left(\overline{Leq(c) - Leq(m)}\right)$$

or, equivalently,

$$\left(\overline{Leq(c)} - \overline{Leq(m)}\right)$$

The energy average, on the other hand, is given by

$$Leq = \overline{Leq} + k\sigma^2,$$

where k is a constant reflecting the distribution of sound levels and σ is the standard deviation in Leq. Thus the true equality expected is not

$$\overline{Leq(c)} = \overline{Leq(m)},$$

but

$$\overline{Leq(c)} + k\sigma c^2 = \overline{Leq(m)} + k\sigma m^2$$

Because of the greater errors associated the microsample generated Leq's,

$$\sigma m^2 > \sigma c^2,$$

implying that Leq(c) > Leq(m) in order for the equality to be maintained.

D-3-3 Temporal Variation

Table D-2 shows the results of the eight multiday measurements upon which the assessment of daily variation was based. Overall daily averages were obtained by averaging the differences between Ldn values obtained for a particular day and the average Ldn for each multiday site. These average differences were then added to the average Ldn obtained over all sites, 60 dB, to obtain the average daily Ldn values.

The daily variation in Ldn shown in table D-2 reflects both true variation in the noise environment and sampling errors inherent in the continuous monitoring procedure. Based upon the discussion of sampling errors in section D-2, the variation may be assumed to be almost entirely true variation.

Table D-2. Five-day Site Ldn Values

Site	Dates of Measurement	M	T	W	TH	F	S	S	Mean	Standard Deviation
San Francisco TR 3870 BL 205	3/9/81 to 3/13/81	54.8	53.3	54.6	58.0				55.2	2.0
San Diego TR 170.01 BL 112	3/13/81 to 3/19/81	53.2	56.8	60.7	54.6		52.9	54.5	55.5	2.9
Tampa TR 113 BL 211	4/10/81 to 4/15/81	60.5	56.9	62.7			61.7		60.4	1.6
Philadelphia TR 148 BL 105	5/3/81 to 5/8/81	63.4	62.5	61.0	66.3			67.4	64.1	2.7
New York TR 5202 BL 108	5/27/81 to 5/31/81			59.4	61.8	59.5	61.3	59.8	60.4	1.6
San Jose TR 5065.03 BL 210	3/6/81 to 3/11/81	51.2	51.1			56.8	49.5	50.7	51.8	2.8
Cleveland TR 1192 BL 104	6/4/81 to 6/10/81		70.2	69.7	68.5	59.3	71.3		69.8	1.0
Chicago TR 6305 BL 108	6/16/81 to 6/22/81		62.0	63.3	64.3	63.2	61.7		62.9	1.1
Mean									60.0	2.0

The hourly noise level histories were obtained by averaging the levels both by hour and by sampling cell, and then taking weighted averages of these results by traffic impact.

D-3-4 Noise Sources

The results concerning source contributions are based upon 700 microsamples and 84,000 individual source identifications and sound level measurements. A two-stage process was used to reduce these data. First, the data obtained in each microsample was reduced to obtain the overall Leq, according to the equation

$$Leq = 10 \times \log 10 \left(\sum_{i=1}^{120} 10^{Li/10}/120 \right)$$

Li - Level obtained in ith measurement of microsample,

the frequency of identification of each source, n/120, where n is the number of times the source was identified, and the Leq(id) for each source,

$$Leq\ (id) = 10 \times \log 10 \left(\sum_{j=1}^{n} 10^{Lj/10}/n \right)$$

Lj - Level measured at time of jth identification.

The acoustical data for a microsample thus contained one Leq value, 26 frequency values (one for each source considered in the survey), and one Leq(id) value for each source whose frequency was greater than zero. If a source was not identified in a microsample, its frequency was zero and its Leq(id) was considered a missing value.

The results for each microsample taken at a particular site were then reduced to obtain a source profile of each site. To control for the various sources of variation, different subsets of the microsamples were used according to the phenomena being considered. Cell by cell variation and factor analysis was based upon microsamples taken at the front only. The frequency used was computed from the equation

$$F = 12/24\ Fd + 3/24\ Fe + 9/24\ Fn$$

Fd - Frequency in front, daytime, microsample

Fe - Frequency in front, evening, microsample

Fn - Frequency in front, nighttime, microsample,

where the fractional weighting factors reflect the number of hours associated with these three time periods. Likewise, Leq(id) was computed according to:

$$Leq(id) = 10 \log 10\ (10^{Leq(id)d} \times 12/24 + 10^{Leq(id)e} \times 3/24 + 10^{Leq(id)n} \times 9/24)$$

Leq(id)d - Leq(id) in front, daytime, microsample

Leq(id)e - Leq(id) in front, evening, microsample

Leq(id)n - Leq(id) in front, nighttime, microsample

The same Fd,e,n and $Leq(id)_{d,e,n}$ descriptors were used to assess variation in source contributions by time of day. To assess variation by side of unit, only microsamples collected during the daytime were considered. Thus, locational variation was eliminated in the consideration of temporal variation, and temporal variation was minimized in the assessment of locational variation, and both locational and temporal variation were eliminated in considering variation by urban area size, population, density, and traffic impact. Insufficient data were available to evaluate the interactive effects of these sources of variation.

D-3-5 Factor Analysis

Analysis of variation with respect to urban area size, population density, and traffic impact began with the definition of the dependent variables. These were the Ldn, and the frequency and Leq(id), based on temporally averaged data collected at the front as described in paragraph D-3-4 of the six selected individual sources and four source classes considered in the analysis.

In cases where a source was not identified at a particular site, its frequency was zero and its Leq(id) considered a missing value.

The independent variables were defined initially as dummy variables which reflected the categories of traffic impact, urban area size, and urban zone population density used to define the sampling cell structure. An initial regression analysis was run using these three variables as well as their cross terms. It was found that the significant factors were traffic impact, density, and the urban area size-density product. This lead to the hypothesis that urban area size is significant only because larger urban areas contain urban zones of extremely high density, so that a "high" density area in a large urban area tends to be significantly more dense than one in a smaller urban area. To test this hypothesis, the density variable was redefined as the logarithm of the actual density. Results of regression analysis performed on this modified set of variables confirmed the hypothesis, with only traffic impact and log 10 (UZ density) found to be statistically significant.

APPENDIX E

ESTIMATION OF CELL POPULATIONS

As described in the text, the cell structure used in the National Ambient Noise Survey incorporates three parameters: urban area (UA) size, urban zone (UZ) density, and traffic impact. The first two of these are based on data available in table 20 of the 1970 Census of the Population - Number of Inhabitants. The traffic parameter is defined in terms of distances from freeways and arterials.

To plan the survey efficiently and to draw national conclusions from it, it was necessary to estimate the 1980 populations corresponding to each cell. This was a straightforward matter with respect to the UA size and UZ density parameters. The difficulty came in apportioning the population according to the traffic impact categories.

This apportionment was accomplished by means of the National Roadway Traffic Noise Exposure Model (NRTNEM) data base.* The model employs a cell structure very similar to that used in the National Ambient Noise Survey and was designed specifically to produce the type of population distribution over distance from roadway information which was desired.

Figure E-1 shows the method used to determine these distributions. It represents the total roadway mileage of a particular roadway classification which runs through the total occupied area of a particular population place size, population density category. The distance $d_1 + d_2$ is the distance from the roadway center of the nearest lane (CNL) at which the clear zone ends and the populated area begins. Thus the populated area within a particular distance d_3 of the roadway is defined by M, the roadway mileage, multiplied by

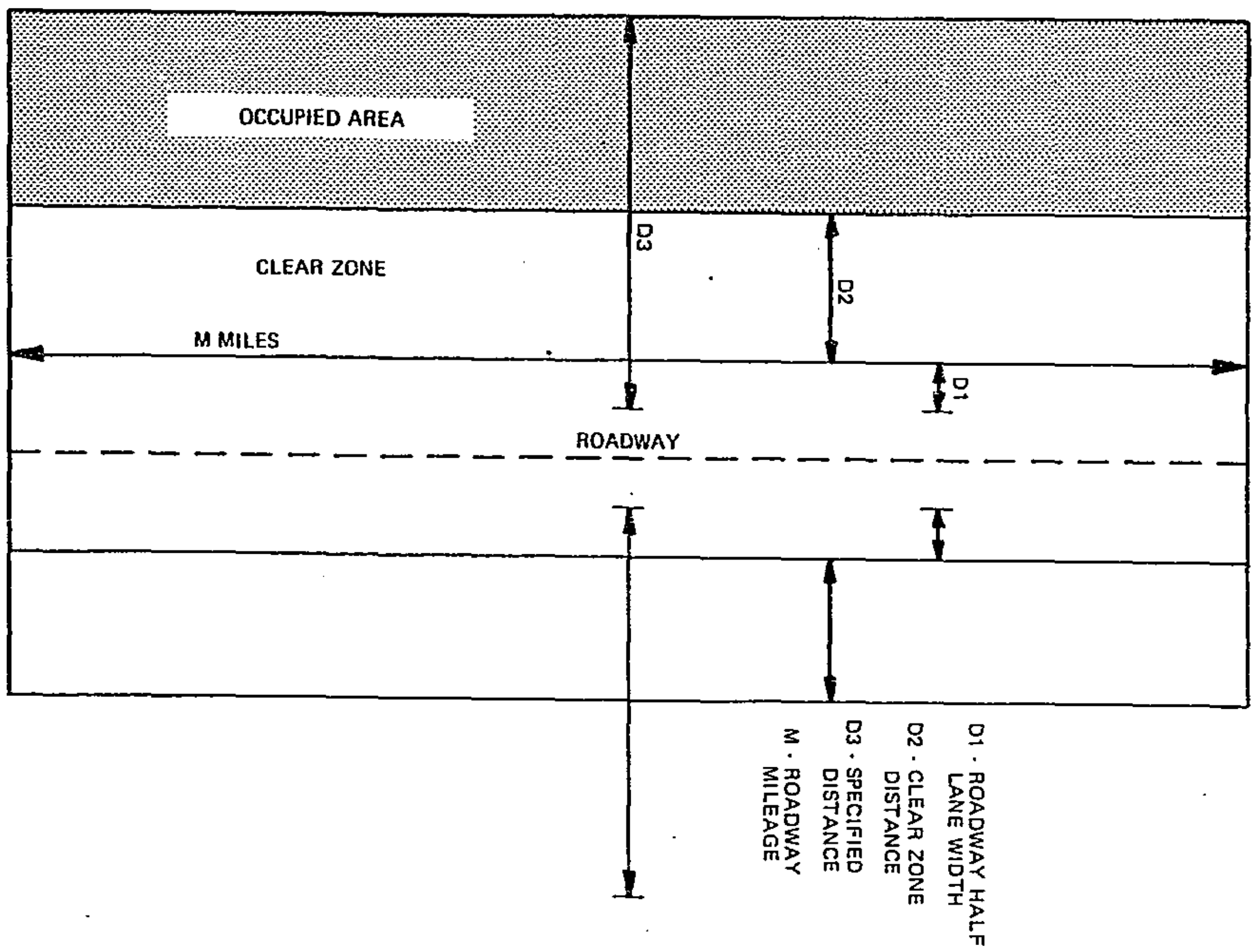


Figure E-1. Method for Estimating Populations Within Specified Distance of Roadway Type the quantity 2 $[d_3-(d_1+d_2)]$. This area, when combined with its population density, defines a population.

Table E-1 shows the population place size and population density categories used in the NRTNEM data base. Population place size is equivalent (though with a few minor deviations) to the urban area size. The population density parameter is the urban zone population density.

Despite these equivalences with respect to the variables employed, the categories used in NRTNEM and the cells used in the National Ambient Noise Survey differ with respect to the intervals of these variables which they represent. In the case of population place size, NRTNEM has nine categories, eight urban and one rural, while the survey cell structure has only two urban categories. Both NRTNEM and the survey employ four categories of population density, but NRTNEM uses logarithmic intervals for its categories, whereas the survey uses linear intervals.

In addition to the population and land area of each cell, table E-1 contains a parameter called P*. This parameter represents a population density adjusted to exclude the land area in each cell which is unoccupied. This parameter thus defines the population density of the occupied area shown in figure E-1.

As the survey considers only urbanized areas, which by definition must include a central city with a population over 50,000, only population place size categories 1-6 of table E-1 are considered in the subsequent calculations and tables.

Tables E-2A through E-2E show the mileage distribution of the six roadway classifications used by FHWA, broken down by average travel speed and the

Table E-1. Distribution of Population and Land Area by Place Size (Index J) and Population Density Category (Index ID)

Based on National Roadway Traffic Noise Exposure Model Data Base

POPULATION PLACE SIZE--INDEX J

Population Density Area--Index ID	PARAMETER	1 >2M	2 1M -2M	3 500k -1M	4 200k -500k	5 100k -200k	6 50k -100k	7 25k -50k	8 5k -25k	URBAN TOTAL	9 RURAL
1	Population	5.61	2.10	0.36	1.61	1.16	1.07	0.47	1.85	14.23	64.18
	Area	134.2	272	63	215	279	329	58	220	1570.2	3,476,938
	p*	64,711	13,451	9,368	9,368	5,831	4,186	13,091	16,988	--	18.0
2	Population	22.28	4.08	2.04	10.43	2.93	2.12	2.98	4.97	51.83	0.0
	Area	3576	775	488	4558	1305	1115	896	1261	13970.0	0.0
	p*	12,638	9,092	6,967	3697.0	3,384	2,863	8,506	10,681	--	
3	Population	21.59	11.13	8.40	6.75	6.84	4.53	3.51	8.46	71.20	0.0
	Area	8358	5080	4426	5790	5266	4195	2230	4527	39872.0	0.0
	p*	6,107	5,014	3,842	2,264	2,011	1,612.0	4,698	6,271	--	
4	Population	0.0	5.35	5.30	0.0	0.0	0.0	1.92	2.70	15.27	0.0
	Area	0.0	4089	4584	0.0	0.0	0.0	2769	5820	17262.0	0.0
	p*	--	5,505	2,336	--	--	--	2,147	1,673	--	
TOTAL POPULATION		49.48	22.66	16.09	18.78	10.93	7.71	8.88	17.98	152.52	64.18
TOTAL AREA		12064.2	10216.0	9561.0	10563.0	6850.0	5639.0	5953.0	11828.0	72674.2	3476938

Total Population = 216.70 million

Total Land Area = 3,549,612.2 square miles

p* = Population/ (Area) (Area Factor), Adjusted Population Density in People per Square Mile

Population Place Size = Urban Area Size

Population Density = Urban Zone Density

Table E-2A. Roadway Mileages

J = Population Place Size
ID = Population Density
K = Roadway Type, where:

1 - Interstates
2 - Urban Freeways
3 - Principal Arterials
4 - Minor Arterials
5 - Collectors
6 - Locals

AVERAGE TRAVEL SPEED 20 MPH

ID = 1
HIGH POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		0	3	16	41	37	94
	2		0	7	21	71	71	172
	3		0	1	4	11	12	31
	4		0	3	17	45	42	119
	5		0	5	24	58	61	149
	6		0	5	29	67	69	171

ID = 2
MEDIUM TO HIGH POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		6	78	438	1085	989	2494
	2		1	19	59	201	203	491
	3		1	6	31	84	95	242
	4		7	69	360	963	886	2514
	5		2	23	110	273	283	699
	6		1	18	99	229	233	579

ID = 3
MEDIUM TO LOW POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		14	182	1025	2540	2314	5837
	2		7	125	384	1321	1333	3216
	3		7	51	280	761	866	2197
	4		9	88	458	1223	1125	3193
	5		7	92	444	1100	1142	2821
	6		4	67	372	860	877	2178

ID = 4
LOW POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		0	0	0	0	0	0
	2		6	101	309	1063	1073	2589
	3		7	53	290	788	897	2276
	4		0	0	0	0	0	0
	5		0	0	0	0	0	0
	6		0	0	0	0	0	0

Table E-2B. Roadway Mileages

J = Population Place Size
ID = Population Density
K = Roadway Type, where:

1 - Interstates
2 - Urban Freeways
3 - Principal Arterials
4 - Minor Arterials
5 - Collectors
6 - Locals

AVERAGE TRAVEL SPEED 30 MPH

ID = 1
HIGH POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		1	8	43	83	76	422
	2		1	16	54	144	145	775
	3		0	2	10	22	25	141
	4		1	9	44	92	85	534
	5		1	13	61	119	123	673
	6		1	14	76	137	140	769

ID = 2
MEDIUM TO HIGH POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		18	202	1138	2213	2017	11225
	2		4	44	152	411	415	2208
	3		2	15	80	171	195	1090
	4		22	182	937	1958	1805	11311
	5		5	60	286	556	577	3146
	6		3	46	257	466	475	2606

ID = 3
MEDIUM TO LOW POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		42	472	2662	5179	4720	26264
	2		28	291	999	2693	2717	14473
	3		20	133	728	1551	1765	9888
	4		29	231	1191	2487	2293	14368
	5		20	241	1154	2242	2328	12695
	6		11	174	967	1753	1787	9803

ID = 4
LOW POPULATION DENSITY AREAS

J	V	K >	1	2	3	4	5	6
	1		0	0	0	0	0	0
	2		22	234	805	2167	2187	11649
	3		21	138	754	1606	1828	10241
	4		0	0	0	0	0	0
	5		0	0	0	0	0	0
	6		0	0	0	0	0	0

Table E-2C. Roadway Mileages

J = Population Place Size
ID = Population Density
K = Roadway Type, where:

1 - Interstates
2 - Urban Freeways
3 - Principal Arterials
4 - Minor Arterials
5 - Collectors
6 - Locals

AVERAGE TRAVEL SPEED 40 MPH

ID = 1
HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		1	5	29	24	21	422
	2		2	10	36	41	41	775
	3		0	1	7	6	7	141
	4		1	6	29	26	24	534
	5		1	9	41	34	35	673
	6		1	9	51	39	40	769

ID = 2
MEDIUM TO HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		24	134	759	626	571	11225
	2		6	30	102	116	117	2208
	3		3	10	54	48	55	1090
	4		30	121	624	555	511	11311
	5		6	40	191	157	163	3146
	6		4	31	172	132	134	2606

ID = 3
MEDIUM TO LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		55	315	1776	1465	1336	26264
	2		37	194	667	762	769	14473
	3		27	89	486	439	499	9888
	4		38	154	793	705	650	14368
	5		26	161	769	635	659	12695
	6		16	116	646	495	506	9803

ID = 4
LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		0	0	0	0	0	0
	2		30	156	537	614	619	11649
	3		28	92	503	455	517	10421
	4		0	0	0	0	0	0
	5		0	0	0	0	0	0
	6		0	0	0	0	0	0

Table E-2D. Roadway Mileages

J = Population Place Size
ID = Population Density
K = Roadway Type, where:
1 - Interstates
2 - Urban Freeways
3 - Principal Arterials
4 - Minor Arterials
5 - Collectors
6 - Locals

AVERAGE TRAVEL SPEED 50 MPH

ID = 1
HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		8	3	16	8	7	0
	2		17	6	21	14	14	0
	3		3	1	4	2	2	0
	4		12	3	17	9	8	0
	5		12	5	24	11	12	0
	6		10	5	29	13	13	0

ID = 2
MEDIUM TO HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		201	78	438	209	191	0
	2		48	17	59	39	39	0
	3		26	6	31	16	18	0
	4		256	69	360	185	170	0
	5		55	23	110	52	54	0
	6		34	18	99	44	45	0

ID = 3
MEDIUM TO LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		470	182	1025	488	446	0
	2		317	112	384	254	256	0
	3		233	51	280	146	166	0
	4		325	88	458	235	217	0
	5		224	92	444	211	220	0
	6		129	67	372	165	169	0

ID = 4
LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		0	0	0	0	0	0
	2		255	90	309	205	206	0
	3		241	53	290	152	172	0
	4		0	0	0	0	0	0
	5		0	0	0	0	0	0
	6		0	0	0	0	0	0

Table E-2E. Roadway Mileages

J = Population Place Size
ID = Population Density
K = Roadway Type, where:

1 - Interstates	4 - Minor Arterials
2 - Urban Freeways	5 - Collectors
3 - Principal Arterials	6 - Locals

AVERAGE TRAVEL SPEED 60 MPH

ID = 1
HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		13	1	6	2	1	0
	2		29	2	7	3	3	0
	3		6	0	1	0	0	0
	4		21	1	6	2	2	0
	5		20	2	8	2	2	0
	6		17	2	10	3	3	0

ID = 2
MEDIUM TO HIGH POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		343	26	147	42	38	0
	2		83	6	20	8	8	0
	3		44	2	10	3	4	0
	4		437	23	120	37	35	0
	5		94	7	37	10	11	0
	6		59	6	33	9	9	0

ID = 3
MEDIUM TO LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		802	60	343	98	90	0
	2		541	37	128	51	51	0
	3		397	17	94	29	33	0
	4		555	29	152	47	44	0
	5		381	30	148	42	44	2
	6		222	22	123	33	34	0

ID = 4
LOW POPULATION DENSITY AREAS

J	V	K>	1	2	3	4	5	6
	1		0	0	0	0	0	0
	2		435	30	103	41	41	0
	3		411	18	97	30	34	0
	4		0	0	0	0	0	0
	5		0	0	0	0	0	0
	6		0	0	0	0	0	0

NRTNEM population place size and population density categories. Table E-3 shows the fraction of these mileages which run through occupied land. Together, tables E-2 and E-3 can be used to construct table E-4, which gives mileages of roadway running through occupied land by roadway classification, population place size category, and population density category. This data is given only for the roadway classifications used in defining the high-traffic-impact-category used in the survey: interstates, urban freeways, principal arterials, and minor arterials.

The data in table E-5 specify values of M as defined in figure E-1 for each combination of roadway classification, population place size category, and population density category. There remains the need to define values of d_1 and d_2. The value d_1, the lane halfwidth of the roadway, is estimated as 7.5 feet for interstates and 6 feet for all other roadways. The value d_2 for each combination of roadway type, urban area size category, and population density category is shown in table E-5.

The high-traffic-impact areas, as defined by the NRTNEM, include all areas within either 300 feet of an interstate or urban freeway, or 100 feet of a principal or minor arterial. The data given in tables E-1 through E-5 can be used to estimate the populations of each of these four areas for each population place size, population density category. These estimates are given in table E-6. This data is then used to construct table E-7, which gives the total high traffic impact population of each category.

To obtain the high-traffic-impact populations in the urban area size, urban zone density categories used in the National Ambient Noise Survey, it is necessary to apportion the NRTNEM categories to the survey categories. Table E-8 shows the 1970 urban population distribution over urban area size and urban zone density, the latter distribution based on the category definitions used in the survey. Tables E-1 and E-8 can be used to perform the necessary apportionment within each urban area size category. The results are shown in tables E-9A through E-9F.

Applying these tables to table E-7 yields the populations of each urban area size, urban zone density, and traffic impact category used in the survey. The resulting estimates are shown in table E-10.

Table E-1 and the subsequent tables based upon it reflect 1974 data. To update these estimates to 1980, the population growth factors shown in table E-11 are used. These growth factors are defined at the level of population place size and are assumed to apply to all population density/traffic impact categories within each category. They are assumed to reflect migration of urban areas within categories as well as net population growth. The application of table E-11 to table E-10 results in table E-12, in which the urban area size categories have been collapsed into the two used for the National Ambient Noise Survey. Table E-12 thus gives the population estimates of the sampling cells used in the survey.

Table E-3. Fractions of Roadway Mileages Which Run Through Occupied Land

	Population Place Size, Index J								
K	1	2	3	4	5	6	7	8	9
1	0.764	0.764	0.764	0.764	0.764	0.764	0.656	0.656	1.000
2	0.738	0.738	0.738	0.738	0.738	0.738	0.679	0.679	1.000
3	0.866	0.866	0.866	0.866	0.866	0.866	0.843	0.843	1.000
4	0.845	0.845	0.845	0.845	0.845	0.845	0.849	0.849	1.000
5	0.852	0.852	0.852	0.852	0.852	0.852	0.867	0.867	1.000
6	0.852	0.852	0.852	0.852	0.852	0.852	0.867	0.867	1.000

J is Population Place Size Index

K is Roadway Type Index

Table E-4. Roadway Mileage Through Occupied Land

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	17.6	37.4	6.9	26.7	26.0	22.2
ID=2	452	109	58	575	124	77
ID=3	1057	711	523	730	503	292
ID=4	0	571	541	0	0	0

Interstates
(K=1)

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	14.8	30.3	3.7	16.2	25.1	25.8
ID=2	382	86	36.9	342	113	88
ID=3	849	560	252	435	455	329
ID=4	0	451	261	0	0	0

Urban Freeways
(K=2)

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	95	114	22.5	79	137	169
ID=2	2529	339	178	2079	636	572
ID=3	5916	2219	1618	2643	2562	2148
ID=4	0	1787	1617	0	0	0

Principal Arterials
(K=3)

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	134	288	34.6	147	189	219
ID=2	3528	655	272	3125	886	744
ID=3	8256	4293	2472	3969	3574	2794
ID=4	0	3456	2561	0	0	0

Minor Arterials
(K=4)

Table E-5. Clear Zone Distances (In Feet) by Roadway Type (K), Population Density Category (ID), and Population Place Size (J)

		Population Place Size, Index J								
K	ID	1	2	3	4	5	6	7	8	9
1	ALL	50.	50.	50.	50.	50.	50.	50.	50.	50.
2	All	30.	30.	30.	40.	40.	40.	40.	40.	50.
3	1	10.	10.	10.	10.	10.	10.	10.	10.	40.
	2	15.	15.	15.	20.	20.	20.	20.	20.	40.
	3	20.	20.	20.	30.	30.	30.	30.	30.	40.
	4	30.	30.	30.	40.	40.	40.	40.	40.	40.
4	1	10.	10.	10.	10.	10.	10.	10.	10.	40.
	2	15.	15.	15.	20.	20.	20.	20.	20.	40.
	3	20.	20.	20.	30.	30.	30.	30.	30.	40.
	4	30.	30.	30.	40.	40.	40.	40.	40.	40.
5	1	5.	5.	5.	10.	10.	10.	10.	10.	40.
	2	10.	10.	10.	20.	20.	20.	20.	20.	40.
	3	15.	15.	15.	30.	30.	30.	30.	30.	40.
	4	20.	20.	20	40.	40.	40.	40.	40.	40.
6	1	5.	5.	5.	10.	10.	10.	10.	10.	40.
	2	10.	10.	10.	20.	20.	20.	20.	20.	40.
	3	15.	15.	15.	30.	30.	30.	30.	30.	40.
	4	20.	20.	20.	40.	40.	40.	40.	40.	40.

Index K denotes highway type; Index ID denotes population density category

Table E-6. Population (in Thousands) High Traffic Impact by Roadway Type

	J=1	J=2	J=3	J-4	J=5	J=6
ID=1	105	46	6	23	14	9
ID=2	525	91	37	195	39	20
ID=3	593	327	185	152	93	43
ID=4	0	131	116	0	0	0

Interstates
d3=300"

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	96	41	3	15	14	10
ID=2	483	78	26	122	37	24
ID=3	518	281	97	95	88	51
ID=4		113	61			

Urban Freeways
d3=300"

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	196	49	7	24	25	23
ID=2	956	92	37	215	60	46
ID=3	1013	312	174	145	125	84
ID=4		109	92			

Principal Arterials
d3=100"

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	276	123	10	44	35	29
ID=2	1334	178	57	324	84	60
ID=3	1413	603	266	218	174	109
ID=4		210	145			

Minor Arterials
d3=100"

Table E-7. High-Traffic-Impact Population (Millions) by Population Place Size and Population Density Category

	J=1	J=2	J=3	J=4	J=5	J=6
ID=1	0.67	0.26	0.03	0.11	0.09	0.07
ID=2	3.30	0.44	0.16	0.86	0.22	0.15
ID=3	3.54	1.52	0.72	0.61	0.48	0.29
ID=4	0	0.56	0.41	0	0	0

Table E-8. Population (Millions) and Percentages by Urban Area Size/ Urban Zone Density Category
Source: 1970 United States Census

	UZ Density (per mile^2)	UA Population >2M	1M-2M	500K-1M	200K-500K	100K-200K	50K-100K
H	(≥4500)	26.3 56.6%	6.02 26.3%	3.49 24.1%	2.40 14.7%	1.74 18.1%	1.04 13.6%
MH	3000-4499	20.2 43.4%	7.50 32.7%	3.41 23.5%	5.00 30.6%	2.27 23.6%	20.4 20.4%
ML	1500-2999	0	7.40 32.2%	7.06 48.7%	7.94 48.5%	4.75 49.5%	3.65 47.7%
L	≤1499	0	2.01 8.8%	.53 3.7%	1.01 6.2%	.85 8.8%	1.40 18.3%
		46.5 100%	23.0 100%	14.5 100%	16.4 100%	9.6 100%	7.6 100%

Tables E-9A – E-9F. Apportionment of NRTNEM Categories to Survey Categories

J=1

	ID=1	ID=2	ID=3	ID=4
H	1.00	1.00		
MH			1.00	
ML				
L				
	1.00	1.00	1.00	1.00

(A)

J=2

	ID=1	ID=2	ID=3	ID=4
H	1.00	0.94		
MH		0.06	0.65	
ML			0.35	0.63
L				0.37
	1.00	1.00	1.00	1.00

(B)

J=3

	ID=1	ID=2	ID=3	ID=4
H	1.00	1.00	0.18	
MH			0.45	
ML			0.37	0.89
L				0.11
	1.00	1.00	1.00	1.00

(C)

J=4

	ID=1	ID=2	ID=3	ID=4
H	1.00	0.11		
MH		0.55		
ML		0.34	0.83	
L			0.17	
	1.00	1.00	1.00	1.00

(D)

J=5

	ID=1	ID=2	ID=3	ID=4
H	1.00	0.28		
MH		0.72	0.07	
ML			0.79	
L			0.14	
	1.00	1.00	1.00	1.00

(E)

J=6

	ID=1	ID=2	ID=3	ID=4
H	0.98			
MH	0.02	0.73		
ML		0.27	0.69	
L			0.31	
	1.00	1.00	1.00	1.00

(F)

Table E-10. Distribution of Urban Population by Urban Area Size, Urban Zone Population Density, and Traffic Impact

Population Density		Large UA's J=1	Medium Small UA's J=2	J=3	J=4	J=5	J=6
H ≥4500	High	3.97	0.67	0.32	0.20	0.15	0.07
	Low	23.92	5.27	3.59	2.56	1.83	0.98
MH 3000-4499	High	3.54	1.01	0.32	0.47	0.19	0.11
	Low	18.05	6.47	3.46	5.27	2.40	1.44
ML 1500-2999	High	0	0.88	0.63	0.80	0.38	0.24
	Low	0	6.39	7.20	8.35	5.02	3.46
L ≤1499	High	0	0.21	0.05	0.10	0.07	0.09
	Low	0	1.77	0.53	1.05	0.89	1.31

Table E-11. Population Growth Factors by Place Size (Index J) For Every Five Years in the Time Stream

		AREA TYPE, J									
		1	2	3	4	5	6	7	8	9	ALL J
PLACE SIZE, THOUSANDS		OVER 2000	1000-2000	500-1000	200-500	100-200	50-100	25-50	5-25	RURAL	
YEAR	VARIABLE	POP(YEAR)/POP(BASELINE)									
1974		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
1980		1.08	1.07	1.07	1.02	1.02	1.02	1.02	1.02	1.12	
1986		1.17	1.16	1.16	1.04	1.04	1.04	1.04	1.04	1.23	
1988		1.19	1.19	1.19	1.05	1.05	1.05	1.05	1.05	1.27	
1990		1.22	1.22	1.22	1.05	1.05	1.05	1.05	1.05	1.31	
1995		1.29	1.29	1.29	1.07	1.07	1.07	1.07	1.07	1.39	
2000		1.36	1.36	1.36	1.08	1.08	1.09	1.09	1.09	1.48	
2005		1.43	1.44	1.44	1.10	1.10	1.10	1.10	1.10	1.57	
2010		1.50	1.51	1.51	1.12	1.12	1.12	1.12	1.12	1.65	

Table E-12. Populations (Millions) of Sampling Cells Used in National Ambient Noise Survey (1980)

	Large UA's		Medium/Small UA's	
	High	Low	High	Low
High	4.29	25.00	1.47	14.96
Medium-High	3.82	19.49	2.20	19.92
Medium-Low	0	0	3.07	31.7
Low	0	0	0.53	5.78

APPENDIX F

THE SITES

LARGE URBAN AREA SITES

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Boston, MA	Boston, MA	Brighton, MA	4	102	Sun-Mon Jul 6-7, 1980
Boston, MA	Outside Central City	Quincy, MA	4180	717	Sun-Mon Jul 6-7, 1980
Boston, MA	Outside Central City	West Newton, MA	3746	107	Mon-Tue Jul 7-8, 1980
Chicago, IL - Northwestern IN	Outside Central Cities	LaGrange Park, IL	8189	320	Fri-Sat May 2-3, 1980
Chicago, IL - Northwestern IN	Outside Central Cities	Chicago Heights, IL	8293	221	Fri-Sat May 2-3, 1980
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	2434	104	Sat-Sun May 3-4, 1980
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	4402	305	Sun-Mon May 4-5, 1980
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	631	102	Tue-Wed Jun 16-17, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	315	302	Wed-Thur Jun 17-18, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	5801	406	Thu-Fri Jun 18-19, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	6109	109	Fri-Sat Jun 19-20, 1981

LARGE URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	6501	107	Sat-Sun Jun 20-21, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	6305	108	Mon-Tue Jun 22-23, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	201	101	Tue-Wed Jun 23-24, 1981
Chicago, IL - Northwestern, IN	Chicago, IL	Chicago, IL	2316	102	Thu-Fri Jul 9-10, 1981
Chicago, IL - Northwestern IN	Chicago, IL	Chicago, IL	609	201	Tue-Wed Jul 16-17, 1981
Los Angeles - Long Beach, CA	Los Angeles, CA	Los Angeles, CA	1926	205	Thu-Fri Mar 20-21, 1980
Los Angeles - Long Beach, CA	Los Angeles, CA	Los Angeles, CA	2352.01	102	Thu-Fri Mar 27-28, 1980
Los Angeles - Long Beach, CA	Outside Central Cities	Burbank, CA	3118	412	Mon-Tue Mar 31-Apr 1, 1980
Los Angeles - Long Beach, CA	Outside Central Cities	Hacienda Heights, CA	4086.01	116	Mon-Tue Mar 31-Apr 1, 1980
New York, NY - Northeastern NJ	Outside Central Cities	Garden City Park, NY	303.202	104	Thu-Fri May 28-29, 1981
New York, NY - Northeastern NJ	Outside Central Cities	Deer Park, NY	1227.02	510	Fri-Sat May 29-30, 1981

LARGE URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
New York, NY - Northeastern NJ	Outside Central Cities	Levitown, NY	5202	108	Fri-Sat May 29-30, 1981
New York, NY - Northeastern NJ	Outside Central Cities	Sayville, NY	1473.02	311	Sat-Wed May 30-Jun 3, 1981
New York, NY - Northeastern NJ	New York, NY	Brooklyn, NY	198	201	Tue-Wed Jun 2-3, 1981
New York, NY - Northeastern NJ	New York, NY	Brooklyn, NY	374	504	Tue-Wed Jun 2-3, 1981
New York, NY - Northeastern NJ	New York, NY	Bronx, NY	394	104	Wed-Thu Jun 4-5, 1981
Philadelphia, PA - NJ	Philadelphia, PA	Philadelphia, PA	148	105	Sun-Thu May 3-7, 1981
Philadelphia, PA - NJ	Outside Central Cities	Warminster, PA	1016.04	33	Mon-Tue May 4-5, 1981
Philadelphia, PA - NJ	Outside Central Cities	Narbeth, PA	2056	201	Tue-Wed May 5-6, 1981
Philadelphia, PA - NJ	Outside Central Cities	Collingdale, PA	4031.03	106	Wed-Thu May 6-7, 1981
Philadelphia, PA - NJ	Philadelphia, PA	Philadelphia, PA	238	201	Thu-Fri May 7-8, 1981
Philadelphia, PA - NJ	Philadelphia, PA	Philadelphia, PA	259	401	Fri-Sat May 8-9, 1981
Philadelphia, PA - NJ	Philadelphia, PA	Philadelphia, PA	348	206	Fri-Sat May 8-9, 1981

LARGE URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
San Francisco - Oakland, CA	Outside Central Cities	El Cerrito, CA	3870	205	Mon-Tue Mar 9-10, 1981
San Francisco - Oakland, CA	Oakland, CA	Oakland, CA	4080	101	Tue-Wed Mar 10-11, 1981
San Francisco - Oakland, CA	San Francisco, CA	San Francisco, CA	307	215	Wed-Thu Mar 11-12, 1981
Washington, DC - MD - VA	Outside Central City	Alexandria, VA	2003.02	203	Sun-Mon Jul 6-7, 1980
Washington, DC - MD - VA	Washington, DC	Washington, DC	78.04	501	Thu-Fri Jul 10-11, 1980
Washington, DC - MD - VA	Outside Central City	Mt. Rainer, MD	8047	204	Thu-Fri Jul 10-11, 1980
Washington, DC - MD - VA	Washington, DC	Washington, DC	52.01	107	Fri-Sat Jul 11-12, 1980

SMALL URBAN AREA SITES

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Allentown - Bethlehem - Easton, PA, NJ	Bethlehem, PA	Bethlehem, PA	101	109	Sun-Mon May 10-11, 1981
Allentown - Bethlehem - Easton, PA, NJ	Bethlehem, PA	Bethlehem, PA	176	715	Sun-Mon May 10-11, 1981
Augusta, GA - SC	Outside Central City	Augusta, GA	103	208	Sun Aug 10, 1980
Binghamton, NY	Outside Central City	Owego, NY	203	905	Tue-Wed May 12-13, 1981
Binghamton, NY	Outside Central City	Union, NY	133.01	318	Tue-Wed May 12-13, 1981
Binghamton, NY	Binghamton, NY	Binghamton, NY	18	202	Wed-Thu May 13-14, 1981
Buffalo, NY	Outside Central City	Niagara Falls, NY	224	411	Sun-Mon May 17-18, 1981
Buffalo, NY	Outside Central City	Niagara Falls, NY	201	101	Sun-Mon May 17-18, 1981
Cleveland, OH	Cleveland, OH	Cleveland, OH	1192	104	Thu-Mon Jun 4-8, 1981
Cleveland, OH	Outside Central City	Wycliff, OH	2009	204	Fri-Sat Jun 5-6, 1981
Cleveland, OH	Outside Central City	Cuyahoga Hts., OH	1659	102	Sat-Sun Jun 6-7, 1981
Cleveland, OH	Outside Central City	Middleburg Heights, OH	1731	509	Sun-Mon Jun 7-8, 1981

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Duluth - Superior, MN - WI	Duluth, MN	Duluth, MN	33	408	Mon-Tue May 12-13, 1980
Duluth - Superior, MN - WI	Duluth, MN	Duluth, MN	14	106	Mon-Tue May 12-13, 1980
Duluth - Superior, MN - WI	Superior, WI	Superior, WI	204	124	Tue-Wed May 13-14, 1980
Duluth - Superior, MN - WI	Superior, WI	Superior, WI	210	109	Tue-Wed May 13-14, 1980
Fargo-Moorhead, ND - MN	Fargo, ND	Fargo, ND	9	422	Thu-Fri May 15-16, 1980
Fargo-Moorhead, ND - MN	Moorhead, MN	Moorhead, MN	206	405	Thu-Fri May 15-16, 1980
Fargo-Moorhead, ND - MN	Moorhead, MN	Moorhead, MN	203	220	Thu-Fri May 15-16, 1980
Fargo-Moorhead, ND - MN	Fargo, ND	Fargo, ND	5	506	Fri-Sat May 16-17, 1980
Fresno, CA	Fresno, CA	Fresno, CA	11	120	Sat-Sun Feb 28-Mar 1, 1981
Madison, WI	Outside Central City	Madison, WI	16.02	104	Wed-Thu Jul 1-2, 1981
Milwaukee, WI	Milwaukee, WI	Milwaukee, WI	170	106	Fri-Sat Jun 26-27, 1981
Milwaukee, WI	Outside Central City	Menomonee Falls, WI	2001	425	Fri-Sat Jun 26-27, 1981

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Minneapolis - St. Paul, MN	Outside Central Cities	Plymouth, MN	266.02	112	Sun-Mon Jun 28-29, 1981
Minneapolis - St. Paul, MN	Outside Central Cities	Bloomington, MN	252	209	Mon-Tue Jun 29-30, 1981
Minneapolis - St. Paul, MN	Minneapolis, MN	Minneapolis, MN	109	413	Tue-Wed Jun 30-Jul 1, 1981
Minneapolis - St. Paul, MN	Minneapolis, MN	Minneapolis, MN	59	103	Tue-Wed Jun 30-Jul 1, 1981
Muskegon - Muskegon Hgts., MI	Muskegon, MI	Muskegon, MI	10	113	Thu-Fri Jun 11-12, 1981
Muskegon - Muskegon Hgts., MI	Muskegon, MI	Muskegon, MI	04	501	Thu-Fri Jun 11-12, 1981
Muskegon - Muskegon Hgts., MI	Muskegon Heights, MI	Muskegon Heights, MI	14.02	606	Fri-Sat Jun 12-13, 1981
Muskegon - Muskegon Hgts., MI	Outside Central Cities	Norton Shores, MI	26.01	201	Sat-Sun Jun 13-14, 1981
Oxnard - Ventura-Thousand Oaks, CA	Thousand Oaks, CA	Thousand Oaks, CA	72.01	307	Tue-Wed Apr 8-9, 1980
Oxnard - Ventura - Thousand Oaks, CA	Thousand Oaks, CA	Thousand Oaks, CA	63	102	Thu-Fri Apr 10-11, 1980
Oxnard - Ventura - Thousand Oaks, CA	Outside Central Cities	El Rio, CA	50	216	Thu-Fri Apr 10-11, 1980

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Oxnard - Ventura - Thousand Oaks, CA	Outside Central Cities	Port Hueneme, CA	42	213	Tue-Wed Apr 15-16, 1980
Portland, ME	Portland, ME	Portland, ME	13	104	Thu-Fri May 21-22, 1981
Portland, ME	Portland, ME	Portland, ME	01	301	Thu-Fri May 21-22, 1981
Portland, OR - WA	Portland, OR - WA	Portland, OR	17.01	516	Mon-Tue Apr 21-22, 1980
Portland, OR - WA	Portland, OR - WA	Portland, OR	66.02	113	Mon-Tue Apr 21-22, 1980
Providence - Pawtucket - Warwick, RI - MA	Pawtucket, RI	Pawtucket, RI	157	413	Fri-Sat May 22-23, 1981
Providence - Pawtucket - Warwick, RI, MA	Outside Central Cities	E. Greenwich, CT	209.02	108	Sat-Sun May 23-24, 1981
Reno, NV	Reno, NV	Reno, NV	05	121	Mon-Tue Mar 2-3, 1981
Reno, NV	Reno, NV	Reno, NV	03	115	Mon-Tue Mar 2-3, 1981
Reno, NV	Outside Central City	Sparks, NV	19	106	Tues-Wed Mar 3-4, 1981
Rochester, NY	Rochester, NY	Rochester, NY	82	209	Mon-Tue Jun 30-Jul 1, 1980
Rochester, NY	Rochester, NY	Rochester, NY	78	601	Tue Jul 1, 1980

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Rochester, NY	Outside Central City	E. Rochester, NY	120	403	Wed-Thu Jul 2-3, 1980
Rochester, NY	Rochester, NY	Rochester, NY	78	512	Wed-Thu Jul 2-3, 1980
Saginaw, MI	Saginaw, MI	Saginaw, MI	103	907	Wed-Thu Jun 10-11, 1981
Saginaw, MI	Outside Central City	Carrolton, MI	107	416	Wed-Thu Jun 10-11, 1981
San Antonio, TX	Outside Central City	Lackland, TX	1719	218	Mon-Tue Apr 6-7, 1981
San Antonio, TX	San Antonio, TX	San Antonio, TX	1702	310	Mon-Tues Apr 6-7, 1981
San Antonio, TX	San Antonio, TX	San Antonio, TX	1212	207	Tue-Wed Apr 7-8, 1981
San Antonio, TX	San Antonio, TX	San Antonio TX	1410	308	Tue-Wed Apr 7-8, 1981
San Bernardino - Riverside, CA	San Bernardino, CA	San Bernardino, CA	58	203	Wed-Thu Feb 25-26, 1981
San Bernardino - Riverside, CA	San Bernardino, CA	San Bernardino, CA	62	205	Wed-Thu Feb 25-26, 1981
San Bernardino - Richmond, CA	Outside Central Cities	Loma Linda, CA	73	606	Thu-Fri Feb 26-27, 1981
San Bernardino - Riverside, CA	Outside Central Cities	Bloomington, CA	36	401	Thu-Fri Feb 26-27, 1981

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
San Diego, CA	Outside Central City	Rancho Bernardo, CA	170.01	112	Fri-Thu Feb 13-19, 1981
San Diego, CA	San Diego, CA	San Diego, CA	80.02	122	Sat-Sun Feb 21-22, 1981
San Diego, CA	San Diego, CA	San Diego, CA	25.02	109	Sat-Sun Feb 21-22, 1981
San Diego, CA	Outside Central City	Oceanside, CA	185.04	104	Mon-Tue Feb 23-24, 1981
San Jose, CA	Outside Central City	Campbell, CA	5065.03	210	Fri-Wed Mar 6-11, 1981
San Jose, CA	San Jose, CA	San Jose, CA	5079.02	101	Fri-Sat Mar 6-7, 1981
Savannah, GA	Savannah, GA	Savannah, GA	28	412	Wed-Thu Jul 16-17, 1980
Savannah, GA	Savannah, GA	Savannah, GA	30	122	Wed-Thu Jul 16-17, 1980
Savannah, GA	Savannah, GA	Savannah, GA	24	209	Fri-Sat Jul 18-19, 1980
Savannah, GA	Savannah, GA	Savannah, GA	38	312	Sat-Sun Jul 19-20, 1980
Savannah, GA	Savannah, GA	Savannah, GA	104	112	Mon-Tue Jul 21-22, 1980
Scranton, PA	Scranton, PA	Scranton, PA	10	208	Tue-Wed Jun 24-25, 1980

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Scranton, PA	Scranton, PA	Scranton, PA	16	311	Tue-Wed Jun 24-25, 1980
Scranton, PA	Outside Central City	Dickson City, PA	115	107	Wed-Thu Jun 25-26, 1980
Scranton, PA	Outside Central City	Blakely, PA	112	225	Thu-Fri Jun 26-27, 1980
Springfield - Chicopee - Holyoke, MA - CT	Outside Central Cities	Enfield, CT	4805	121	Sun-Mon May 24-25, 1981
Springfield - Chicopee - Holyoke, MA - CT	Chicopee Falls, MA	Chicopee Falls, MA	8111	115	Mon-Tue May 25-26, 1981
Springfield - Chicopee - Holyoke, MA - CT	Chicopee Falls, MA	Chicopee Falls, MA	8113	307	Mon-Tues May 25-26, 1981
Syracuse, NY	Syracuse, NY	Syracuse, NY	108	107	Thu-Fri May 14-15, 1981
Syracuse, NY	Syracuse, NY	Syracuse, NY	125	215	Thu-Fri May 14-15, 1981
Tampa, FL	Outside Central City	Lake Carroll, FL	113	211	Fri-Wed May 10-15, 1981
Tampa, FL	Outside Central City	University, FL	108	502	Fri-Sat Apr 10-11, 1981
Tampa, FL	Tampa, FL	Tampa, FL	33	405	Mon-Tue Apr 13-14, 1981
Tampa, FL	Tampa, FL	Tampa, FL	18	703	Tue-Wed Apr 14-15, 1981

SMALL URBAN AREA SITES - Continued

Urban Area	Urban Zone	Community	Tract	Block	Dates Measured
Waterbury, CT	Waterbury, CT	Waterbury, CT	3523	105	Tue-Wed May 26-27, 1981
West Palm Beach, FL	W. Palm Beach, FL.	W. Palm Beach, FL	28	114	Thu-Fri Apr 16-17, 1981