EPA 550/9-81-421

COMMUNITY NOISE ASSESSMENT MANUAL

SIMPLIFIED NOISE STRATEGY MANUAL

July 1981

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
Washington, D.C. 20460

Under Contract No. 68-01-4944

V-96-01
II-A-170

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE	5. REPORT DATE
Simplified Noise Strategy Manual	July 1981
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Mr. Mones E. Hawley	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Jack Faucett Associates, Inc. 5454 Wisconsin Avenue Chevy Chase, Md. 20015	11. CONTRACT/GRANT NO. 68-01-4944
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
U.S. Environmental Protection Agency 401 M Street, S.W. Washington, D.C. 20460	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report was prepared by EPA, Office of Noise Abatement and Control, in support of its function to provide technical assistance to communities. It is one of nine which comprises the Community Noise Assessment Manual. The Manual provides a comprehensive and computerized system for assessing the noise problems of a community and then planning a noise control strategy for its abatement. This manual's objectives are the same as those described in the "Strategy Guidelines for Developing a Community Noise Control Program." It provides however a simplified and manual system for planning the noise control strategy for abating a community's noise problems. It assists communities in determining, in an objective manner, the efficient allocation of funds for reducing the adverse effects of noise in their community. By following a step-by-step written procedure, a noise planner can be assisted in selecting the most cost-effective noise abatement measures and the amount of money which should be spent on each. The primary criterion for optimization is based on economic and acoustical data gathered in the community.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Releasable to the public	Unclassified	94
	20. SECURITY CLASS *(This page)*	22. PRICE
	Unclassified	

EPA Form 2220-1 (9-73)

TABLE OF CONTENTS

SIMPLIFIED NOISE STRATEGY MANUAL

I. INTRODUCTION

A. PURPOSE

The purpose of this document (it is referred to as the Manual throughout) is to assist community officials in planning local noise control programs. (The term community is used throughout this handbook to designate a city, town, borough, township, parish, county, or other unit of government, below that of a State, for which a single noise abatement and control program can be established.) Only noise on public property or which extends across private property lines is considered; occupational noise is not treated in this Manual.

The Manual is intended to be read by elected executives and legislators and by administrative specialists in the community's health, environmental, planning, building, and police departments. Some basic knowledge of sound, noise control, and acoustical measurements is assumed, but references are given to assist readers to obtain this background.

The handbook can be used two ways:

1) It can help to provide the information that is necessary to use the Strategy Guidelines document which is described in the next paragraph, and

2) It can be a rough-and-ready substitute for the Strategy Guidelines document in situations in which the size or length of the noise control programs do not justify employing that document's more elegant and sophisticated techniques.

All users are urged to fill out and send in the sheet at the back of the Manual so that other officials can profit from one another's experience.

B. THE USE OF THE MANUAL WITH THE STRATEGY GUIDELINES DOCUMENT

The U. S. Environmental Protection Agency contracted for the development of a three-piece Community Noise Assessment Manual. The three pieces are a Social Survey Workbook,[1] which describes a method for making an attitudinal survey of noise problems in a community; an Acoustical Survey document[2] which describes the methods for making an acoustical survey of noise problems in a community, and a Strategy Guidelines document[3], which describes how to use these survey results and other data to choose an optimum noise control program for a chosen period and a chosen budget. The introduction to the Strategy Guidelines document describes it well.

> "Since the number of possible combinations of noise sources and corresponding countermeasures to reduce their impact can be quite large, a computer-based approach is therefore called for to develop optimum scenarios for expenditures. The procedure described in this manual utilizes an optimization computer model called "NOIZOP" which selects the most cost-effective noise abatement measures and the amount of money which should be spent on each. The primary criterion for optimization is based on economic and acoustical data gathered in the community. While the procedures involved in obtaining cost estimates for the noise countermeasures and noise level data for the community noise sources to be abated are somewhat involved, the overall approach is conceptually quite simple and, even without use of a computer, much of the material will provide very useful guidelines for devising noise control strategies of any desired detail."[4]

The Manual uses material from the Strategy Guidelines document and assists in supplying the economic and acoustic data and the cost estimates that the Strategy Guidelines document refers to.

---

[1] *"Community Noise Assessment Manual, Social Survey Workbook", Wyle Research, El Segundo, California and Institute for Social Science Research, University of California, Los Angeles, California, July 1978.*

[2] *"Community Noise Assessment Manual, Acoustical Survey," Wyle Research, El Segundo, California (draft report), April 1978.*

[3] *"Community Noise Assessment Manual, Strategy Guidelines," Wyle Research, El Segundo, California, August 1979.*

[4] *Ibid, p. 1-1.*

C. USE OF THE MANUAL AS AN INDEPENDENT DOCUMENT

The Strategy Guidelines document and the Manual both use approximately the same approach to guiding the community officials in their choice of a noise control and abatement strategy. Exhibit I-1 illustrates the systematic flow of information that is used. The top portion of the exhibit shows the steps in describing the noise situation. The description should be completed before either the Strategic Guidelines document or the Manual is used. The EPA methods for performing acoustical and attitudinal surveys are preferred for using either document, but the Strategic Guidelines document uses a computer program in the analysis phase, and, if other survey techniques have been used, it will be harder to describe the noise situation in a way that the computer can accept as an input. Section II of this Manual discusses the definition of the noise problem.

The bottom portion of the exhibit indicates the contents of this Manual. They are data concerning the methods that can be used to prevent, control, and abate community noise. In this Manual and in the Strategic Guidelines document such methods are called "countermeasures". Section III of this Manual describes the countermeasures and the ways which are appropriate for measuring their effectiveness. Section IV contains the best and most complete information currently available on the factors of costs, effectiveness, and time of effectiveness or implementation of each countermeasure. The data consist of information from the Strategic Guidelines document, from reports by EPA and other sources that have become available since the Strategic Guidelines document was prepared, and from data that Jack Faucett Associates has developed on this contract. Section V contains instructions for using the material in the previous sections to develop a noise abatement and control plan.

The central portion of the exhibit indicates the analysis and the planning processes that are necessary to produce a noise abatement and control plan. An important additional contribution to this plan is the key local information concerning limitations and constraints imposed by the local situations. They frequently take the form of statements such as the following: "Don't plan to spend more than $50,000 per year for two years", "Don't do anything that would give local industries an incentive to move out of town", "Try to avoid having to get the approval and cooperation of the Health Department", "Don't crack down too hard on snowmobiles, for they get a very good press when they move essential people to their jobs in blizzards". This sort of contribution is absolutely essential to the production of a feasible plan. The thorough, contextual understanding of this contribution and of the noise survey information is the reason the planning process must be done by local officials.

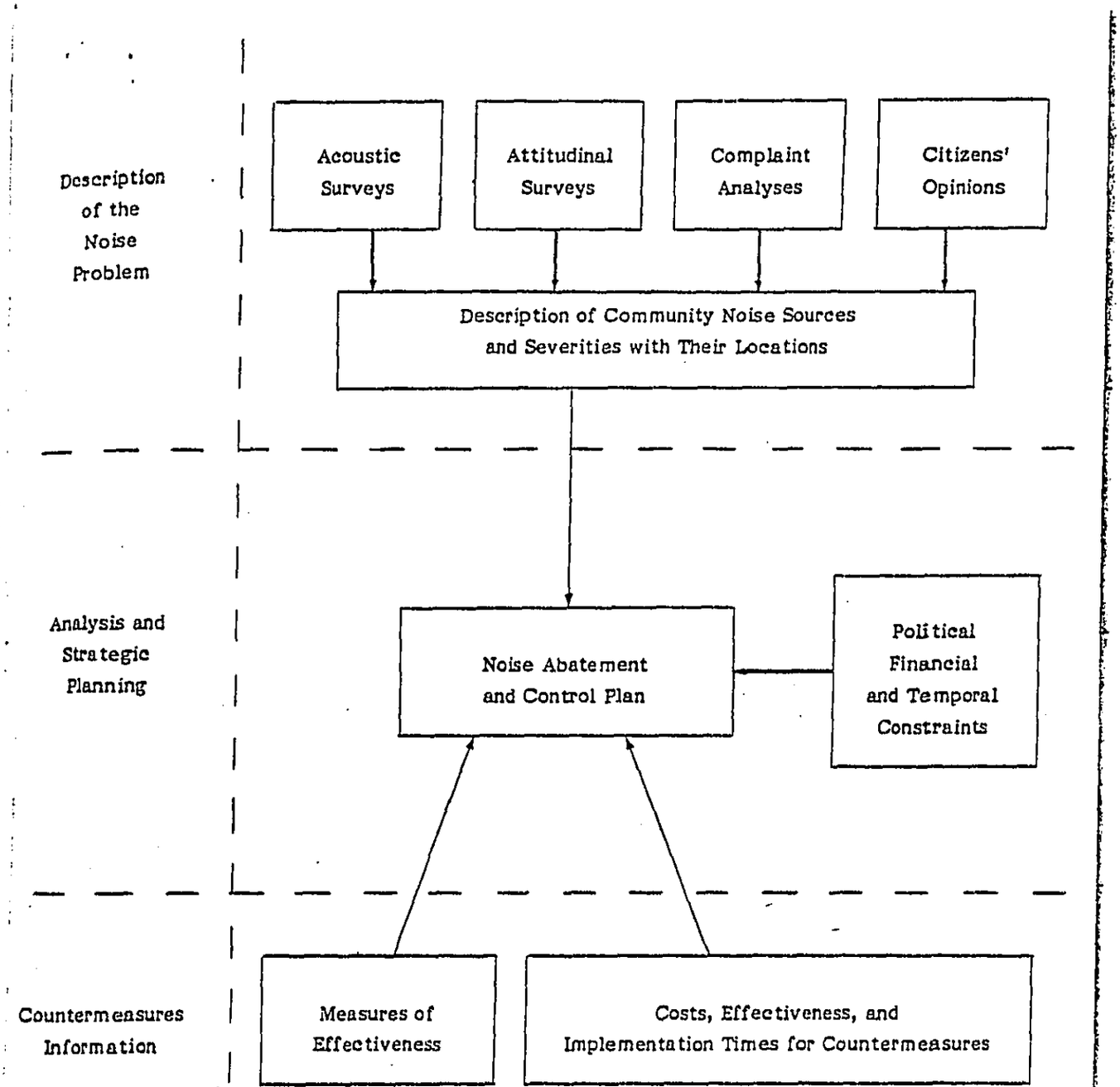


EXHIBIT I-1: NOISE ABATEMENT AND CONTROL PLANNING PROCESS

D. NEED FOR ADDITIONAL COST-EFFECTIVENESS INFORMATION

As is described in Section IV, in many areas of noise control and abatement there are few data concerning costs and almost no reliable data on effectiveness. In addition to the normal difficulties of gathering information of this sort, there are some systematic reasons for these deficiencies.

From the very beginning of the Federal noise abatement and control program it has been recognized that a national program required the support of Federal, State, and local governments. Federal authority for some sources of noise preempts State and local authority to regulate a product both when it is sold and when it is operated. The most important examples are military operations, trains, and interstate motor carriers. However, the Federal government can regulate most products only as new equipment offered for sale in interstate commerce. Only State and local governments can regulate such products as operational equipment. Many sources, such as personal noise sources, can be regulated only at the State or local levels. Hence, it was always stated that the Federal program will not be effective unless State and local programs are in existence and effective.

The costs and benefits of the Federal programs have been studied and estimated. The EPA background document of each regulated product includes an estimate of the impact of the regulations in terms of noise reduction for the people who are exposed to the noise and in terms of the economic impact on those who manufacture, sell, operate, and maintain the products. The economic impact on society in general, on the national economy, on the balance of trade position, and on the competitive position of the U.S. in world trade all are studied for each product.

In the past few years there has been a program of investigation of the cost to State and local governments of particular noise abatement programs, although there are few data yet available. Strong efforts to obtain similar data on the effectiveness of the programs at the State and local levels are just beginning. Therefore, users of this Manual are urged to send any data they have to the State and Local Programs Division of the EPA's Office of Noise Abatement and Control. The sheet at the end of this Manual has been provided for convenience in noting the experience and data each user can furnish for the benefit of all.

II. SURVEY INFORMATION AND BACKGROUND INFORMATION REQUIRED

A. DEFINITION OF THE NOISE PROBLEM

Exhibit I-1 indicated that there are four potential ways of collecting the information from which the community noise problem may be defined. These are

- Acoustical surveys in which physical measurements are made of noise levels,
- Attitudinal surveys in which residents are questioned about their concern for noise and its abatement,
- Complaint analyses in which the logs of police, health, environment, and animal control departments are examined, and
- Citizens' opinions collected from elected and appointed officials, newspaper and broadcast correspondents, neighborhood advisory councils, town meetings, citizens' committees, fraternal and business clubs, and similar sources.

These four ways normally will not produce consistent or even similar pictures of the community noise situation, because the four ways use different methods and measure somewhat different things. As is discussed below, even a single method can produce different results depending on just when and how it is used.

Exhibit II-1, from the Strategy Guidelines document, shows the differences in ranking of different noise sources depending on the measure that is used. The ranking at the top is in terms of the long term overall contribution to the overall noise level, the middle graph shows the relative rating of a single event from each source, and the bottom graph shows the attitudinal response to each of the sources.

When several different methods are used, they will produce results that differ because they are used at different times and places, and because the act of investigating the noise condition in one way may influence the response in another. The following hypothetical, but realistic, situation illustrates the difficulty.

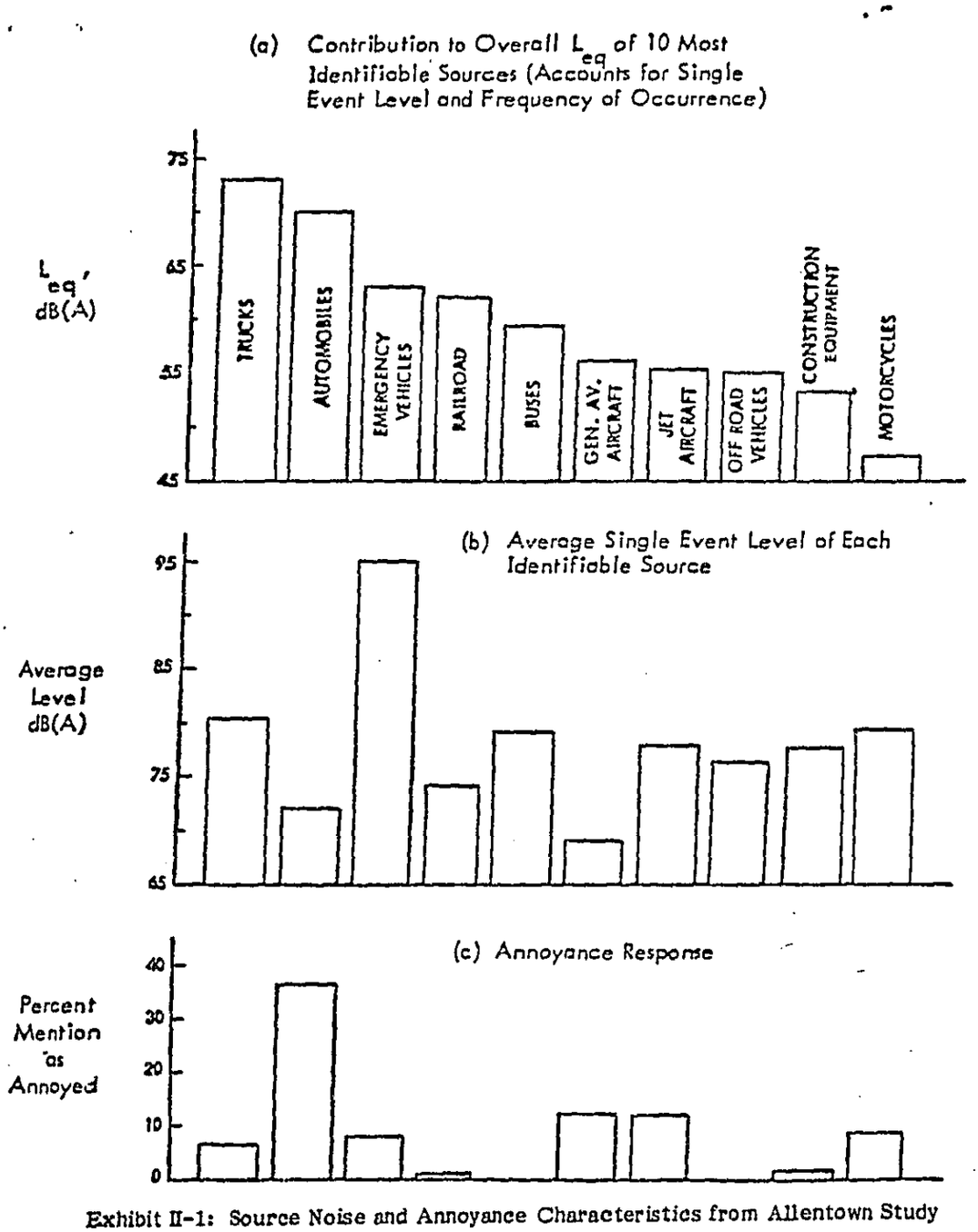


Exhibit II-1: Source Noise and Annoyance Characteristics from Allentown Study

Hypothetical Example

1. *A citizen's group is formed one summer to protest the racing and hill climbing of off-road motorcycles and cars on a privately owned tract of land in a residential zone.*

2. *The group meets with local officials and, in the discussion both parties decide that there is a lot of noise in the community and that other neighborhoods also may have disturbing or dangerous situations. The discussions are reported in the newspaper.*

3. *City officials decide to conduct an attitudinal survey of citizens' attitudes about noise and other environmental factors, to follow it with an acoustical survey, to analyze complaint records, and to hold a public meeting.*

4. *After the surveys and the hearings, the city council passes an ordinance and sets up a noise program, which includes a noise complaint center for which the telephone number is widely advertised.*

When the four methods of describing the noise situation are compared it is found that there are several disparities.

1. *The analysis of complaints made to the police during the previous year shows that loud radios, loud parties, barking dogs, and early morning trash collections were the chief sources of complaints. Complaints about off-road vehicles stopped (perhaps because of informal communications) after the police investigated and began to answer that there was no law that the city attorney would prosecute against using such vehicles on private property and that the owner had lodged no complaint against the use of his land.*

2. *The attitudinal survey which was conducted in the late autumn, showed that the chief causes for dissatisfaction were emergency sirens, construction noise, barking dogs, and general vehicular traffic. Although the off-road vehicles had ceased operation as the weather became cold and the*

ground became muddy, in the neighborhood of the original complaints, these vehicles were mentioned as major irritants. Some interviewers too far away to have heard the off-road vehicles complained about them after they no longer operated.

3. *The acoustical survey, which was undertaken in the winter, revealed that tire noise from cars and trucks and exhaust noise from trucks dominated the long term noise levels in most parts of the community. Chain saws and trash trucks were significant sources in the quietest neighborhoods, but sirens, off-road vehicles, and animals did not contribute enough noise to the overall long term noise levels to be detectable. Construction activity had ceased when the ground froze, but because there had been no snowfall, there was no contribution from snow removal equipment.*

4. *After the noise abatement program was started, the number of complaints to the noise complaint center was high, but the number of complaints the police received did not decrease. The callers thought that now something would be done in response to the complaints and they called the animal control program, the police, and the complaint center itself much more frequently than they had called in the previous year.*

Clearly in a situation like this no one method of investigating the community noise situation will be sufficient, and even in combination, the several methods must be used cautiously and constructively by skilled interpreters who are aware of the sources of error in each method.

The acoustical and attitudinal survey techniques are sound and have been thoroughly developed and tested in several communities. Their results are likely to be quite consistent if they are administered at approximately the same time (the attitudinal survey should preceed the acoustical survey to avoid biasing the respondents into being sensitive to noise problems). In many North American cities there are large differences in snowfall, rain, wind speed, wind direction, and temperature during the year. There are differences in the numbers and activities of the sources of noise, in the propagation paths and absorption of the noise, in the weather induced ambient noise level, and in the activities and acoustic insulation of the receivers of the noise.

There are seasonal differences in the attitudinal responses as well, frequently accompanied by identification of different major sources of noise, e.g. snowmobiles vs. lawnmowers or snow plows vs. air conditioners. Some of the differences may not be seasonally related but are caused by changes in aircraft flight patterns because of wind shifts. A good description of the acoustical noise environment of a community should include consideration of seasonal and weather differences.

There are also large variations in the noise levels and the noise sources with differences in the days of the week. In Allentown, Pennsylvania differences between the noise levels on weekends and on Monday through Friday were only about one decibel alongside a major roadway, but amounted to nine decibels in residential zones. In other zones of activity the differences between the weekend and the Monday-through-Friday sound levels were four, five, or six dB.

Complaint data are a function of the response the complainant receives and of the way in which he lodges his complaint. Almost all complaints are lodged on the telephone. A family fight may be reported and recorded as anything from a noise disturbance to an attempted homicide, depending on the caller's voice and choice of words. Many complaints are parts of neighborhood fueds or are expressions of disapproval of others' conduct. The person who accepts a complaint frequently recognizes the voice of a regular caller and chooses a response by the investigating department that is suitable to what experience has shown about such situations.

Some complaint information is biased for other reasons. For example, in some large cities there are sections from which complaints about the environment are almost never received because many aliens without valid entry papers are resident there. Such communities avoid any officials' inquiries and investigations. In other areas loud industrial noise sources are not the object of complaints because most of the neighborhood is dependent on the industry for employment.

Many citizens' groups are formed in response to one particular source or class of noise. The other sources of noise should not be neglected in the noise abatement and control program. A good, comprehensive description of the noise situation in a particular community will include information from as many sources as is reasonably possible, and the officials who prepare the description should participate actively in the preparation of the noise control program plan.

B. BACKGROUND INFORMATION REQUIREMENTS

Background information on costs and constraints should be collected by the local officials before the planning process proceeds.

1. Cost Information

In preparation for the comparison of the cost-effectiveness of the various countermeasures, the community officials should assemble costs, measured in the terms that the community's legislative and executive officers regularly use for other programs, of personnel and equipment of the sort that are typical of noise control programs. Examples of costs for typical programs and for individual cost elements in some communities are given in Section IV, but each community that intends to use this Manual should estimate at least the costs per personyear (including such fringe benefits, amortized pension costs, and overheads as they are commonly used in budgeting the community's municipal programs) of the following kinds of people:

(a) A supervisor of a noise abatement program.

(b) An environmental officer or a health officer.

(c) A building officer.

(d) A basic-level (patrolman, private, or the equivalent) police officer with a proportionate share of the costs of an equipped police cruiser.

(e) A basic-level motorcycle police officer (if the community uses them) with the premium pay, if any, and a proportionate share of an equipped motorcycle.

(f) A public information/citizen awareness officer.

(g) An instrument technician capable of storing, adjusting (but not repairing), and keeping calibration records for electronic instruments such as radar speedometers and two-way radios.

(h) A clerk typist.

Section IV includes general, national ranges of costs for the following abatement steps, but if the community has recent specific experience, it should collect the pertinent information for its own future use.

Cost per linear foot of highway or railroad noise barriers.

Cost per square foot for construction of interior partitions to Sound Transmission Class (STC) of approximately 40, 50, and 60.*

Cost per square foot of retrofitting and of constructing exteriors walls of residences to various Exterior Wall Noise Ratings* or Shell Isolation Ratings.*

Cost of equipping transit buses and school buses with state-of-the-art mufflers and other noise reducing equipment and of maintaining this equipment.

Cost of equipping city owned (or leased or contracted for) street cleaning vehicles, snow plows, dump trucks, trash collection trucks, chain saws, limb chippers, construction equipment, and construction vehicles with mufflers and other state-of-the-art noise reduction equipment and of maintaining this equipment.

Cost of retrofitting all burglar alarm systems in the community with a timed cut off.

Cost of fitting all newly installed burglar alarm systems with a timed cut off.

It is desirable to collect general cost factors based on community experience applicable to specific examples of the following kinds of noise abatement alternatives. These factors will be used to estimate the cost of specific cases when they are suitable as alternative noise abatement methods:

Imposing curfews on nonemergency construction and repair work
Imposing curfews on loading and unloading at commercial establishments

See Section IV for details of the specification.

Rerouting traffic
Installing quiet zone signs
Establishing a complaint response center
Operating a public awareness program
Operating an educational program for children and adults
Operating an animal control program

These cost estimating factors should be compiled in the form specified in the Strategy Guidelines document if the NOIZOP computer program will be used, but if this Manual is to be used as a substitute, the discount factors can be ignored if it is the community's policy to do so. Some communities will wish to budget for the establishment of the noise control program, enactment of the required legislation, preparation of the implementing regulations, and training of the enforcement staffs. Other communities will be concerned only with the cost of maintaining and enforcing a program after it has been started. One indication of the size of the budget that the citizens will support is given by the responses to a question of this sort put to the interviewees in Allentown, Pennsylvania. The results are shown in Exhibit II-2.

2. Constraint Information

Section I.C described a group of local constraints on the noise control plan. Community officials should establish these constraints as soon as possible and certainly before the plan is prepared. The following constraints should be considered:

An estimate of the maximum and a most-likely annual budget for a line-item noise abatement and control program.

A statement of the planned duration of the program and the periods at which progress will be evaluated and compared with the plan.

Determinations whether any countermeasures are unacceptable to the local government and whether any are mandatory regardless of their cost-effectiveness.

Identification of any sources of noise which are not to be disturbed.

Legal limitations on the community's program because of State or county preemption or precedent for nonenforceability.

III. NOISE SOURCES AND COUNTERMEASURES

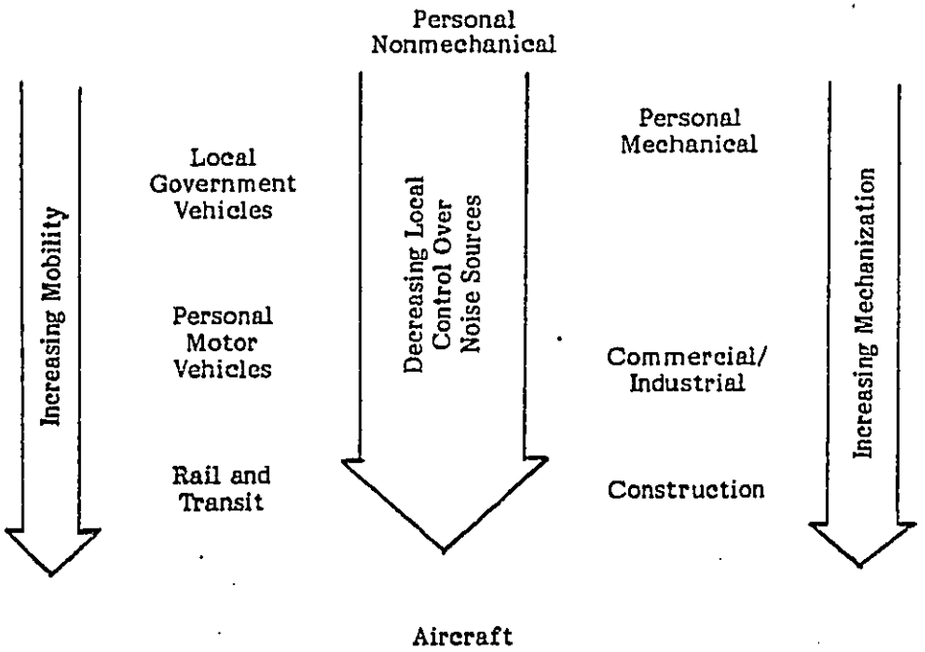
A. NOISE SOURCES

Although there are many sources of noise in a community, the local government is better able to control some of the sources than others. Strictly local problems such as animals, gatherings of people, and amplified sound systems are solely the responsibility of the local government, but as the sources become more complex mechanically and more mobile, there are legal, technical, and financial reasons that make the sources more susceptible to State and to Federal control. Exhibit III-1 illustrates the relative intergovernmental roles in community noise control. In the case of many sources of community noise the local government has only partial, and perhaps only persuasive, influence or control. Exhibit III-2, taken from the Strategic Guidelines document, lists the noise sources that are considered there. This Manual groups these same sources slightly differently and includes some additional ones.

Exhibit III-3 shows the sources of community noise as they are treated in this Manual. Domestic and transportation noise sources are listed in somewhat greater detail because, as is discussed in the next section, there are some countermeasures that are more applicable at the local level to some of these sources than to others. The community officials who use this Manual may wish to combine several sources for common treatment in their plans if it is convenient for them to do so. If the NOIZOP computer program is to be used, the arrangement of sources in the Strategic Guidelines document should be followed strictly.

B. COUNTERMEASURES AGAINST NOISE

Countermeasures are methods available for communities for preventing, abating, and controlling noise. There are many countermeasures and they are difficult to classify into neat sets. Exhibit III-4, from the Strategy Guidelines, shows the classification system used in that document. In order to simplify the use of this Manual as an input to the Strategy Guidelines, the countermeasures in the Manual are virtually identical to those in the other document. The use of nuisance ordinances and of animal control programs has been added, and the "noise standard" heading in the Strategic Guidelines has been divided into source-distance standards and property-line standards in this document.



A Community's Ability to Control Community Noise Is Greatest in the Areas of Personal Noise and Decreases as the Noise Sources Become More Mechanical and More Mobile

1. Personal nonmechanical sources: loud talking, whistling, or singing; loud parties; fighting; pets; playing; musical instruments; sporting events; outdoor concerts; public meetings.
2. Personal mechanical sources: radio, TV, phonograph; yard equipment; power tools; airconditioners; powered model boats and planes; snowmobiles; offroad motorcycles, powerboats.
3. Government service vehicles: snowplows, trash collection trucks; limb trimmers and chippers; sprayers; street cleaners; emergency vehicles with sirens.
4. Stationary industrial/commercial sources: HVAC equipment; industrial processes; loading and unloading.
5. Construction equipment: tractors, graders, excavators, pavement breakers, cranes, air compressors, pile drivers, blasting.
6. Motor vehicles: motorcycles, cars, trucks, and buses.
7. Trains and rapid transit vehicles.
8. Aircraft: military, commercial, and private fixed wing and helicopters

EXHIBIT III-1: Intergovernmental Roles in Community Noise Control

Category	Source	Examples
Stationary	Commercial/Industrial	Power Plant, Railroad Yard, Foundry
	Construction	Highway, Utility, or Building Construction
	Entertainment Center	Race Track, Music Clubs, Outdoor Theater, Bars
Aircraft	Jet	Commercial, Military, Private
	Small Plane	Single-engine Propeller
	Helicopter	Police, Military, Commercial
Rail	Trains	Freight, Passenger, Subway, Streetcar, Monorail
Traffic Vehicle	Traffic	Major & Minor Arterials, Collectors and Boulevards
	Motorcycle	Mo-Ped, Street Cycle, Police Cycle
	Truck	Dump, 18-wheeler, Refrigeration
	Bus	Transit, School, Intercity
	Auto	Sedan, Sports Car, Van, Pickup Truck
	Highway	Freeway, Major High-speed Throughway
Other Vehicle	Service	Garbage Truck, Street Sweeper, Snowplow
	Emergency	Police, Fire, Ambulance, Sirens
Domestic	Pets/Animals	Dogs
	Neighbors' Homes	Stereo Music from within Neighbors' Homes
	Air Conditioners	Air Conditioners, Heat Exchangers and Fans
	Garden Equipment	Lawnmowers, Edgers, Trimmers

EXHIBIT III-2: Categories of Community Noise Sources Considered in the Strategic Guidelines Document

Domestic Noise Sources
- Singing, shouting, whistling
- Playgrounds, sports areas
- Parties
- Quarrels
- Musical instruments
- Radios, TVs, phonographs
- Model engines
- House and yard machinery
- Air conditioners
- Plumbing (multi-family units)
- Pets

Commercial Noise Sources
- Alarms
- Telephones
- Office machines
- Elevators
- HVAC equipment
- Refrigerator trucks
- Sound trucks
- Public address systems
- Rock concerts
- Discotheques, dance halls, bars
- Sports events
- Race tracks

Industrial Noise Sources
- Construction equipment
- Agricultural equipment
- Manufacturing equipment
- Extractive equipment

Transportation Noise Sources
- Highway and expressway traffic
- Street traffic
- Motorcycles
- Trucks
- Buses
- Sirens
- Horns
- Tire peeling
- Revving up engines
- Street cleaners
- Snowplows
- Fuel oil trucks
- Garbage trucks
- Branch chippers
- Off-road vehicles
- Snowmobiles
- Motorboats
- Rapid transit
- Railroads
- Propeller airplanes
- Jet airplanes
- Helicopters

EXHIBIT III-3: Community Noise Sources Treated in This Manual

Abatement Alternatives	Example *
Operational Restrictions	
Noise Standard	Motor vehicles shall not exceed 86 dB at 15m in speed zones above 64km/h (40 mph).
Operational Controls	1. Speed limit in residential areas changes from 72 to 56km/h (45 to 35 mph).
	2. Vehicles shall not operate with excessive acceleration (except where safety requires).
Area Restrictions	No thru-trucks allowed in hillside area.
Time Restrictions	No loud music exceeding 70 dB at property line allowed after 10 P.M.
Permits	On all construction projects exceeding $10,000 value, equipment must meet municipal noise standard X.
Land Use Restrictions	
Barriers	Construct barrier between highway and school.
Building Insulation	Insulate all buildings near airport where $L_{dn} > 75$ dB.
Compensation	Reimburse residents under flight path for lowered property values.
Population Relocation	Relocate residents living in airport areas where $L_{dn} > 75$ dB.
Planning/Zoning	1. Build new highway through industrial area instead of residential area.
	2. Restrict future housing developments near airport.
Building Codes	Extra insulation required in zones where $L_{dn} > 65$ dB.
Tax Measures	
Tax Incentives	Commercial establishments installing quiet outdoor furnaces receive tax break.
Tax Penalty	Plants are charged $500 per dB in excess of 70 dB (L_{dn}) measured at property line per year.
New Product Regulations	
Noise Standard	New lawn mowers sold in the city may not exceed 75 dB at 7.5 m.
Labeling	New vacuum cleaners sold in the city must be acoustically labeled.
Equipment Standard	
Maintenance	Registered automobiles must be inspected for proper maintenance once every two years.
Retrofit	All motorcycles must have a muffler that produces an insertion loss of at least 20 dB.
Other Alternatives	
Education	1. Broadcast once-a-month radio programs to help consumer choose quiet products.
	2. Inform local airport and pilots of noise-sensitive areas.
Complaint Mechanism	Establish noise hotline in cooperation with police.

* These examples are illustrative and may not completely describe details which must be specified if the abatement alternative is to be properly established. Products mentioned as targets of abatement action may not be the most important noise sources to control.

EXHIBIT III-4: List of Abatement Alternatives Which Local Governments May Apply to Community Noise Sources

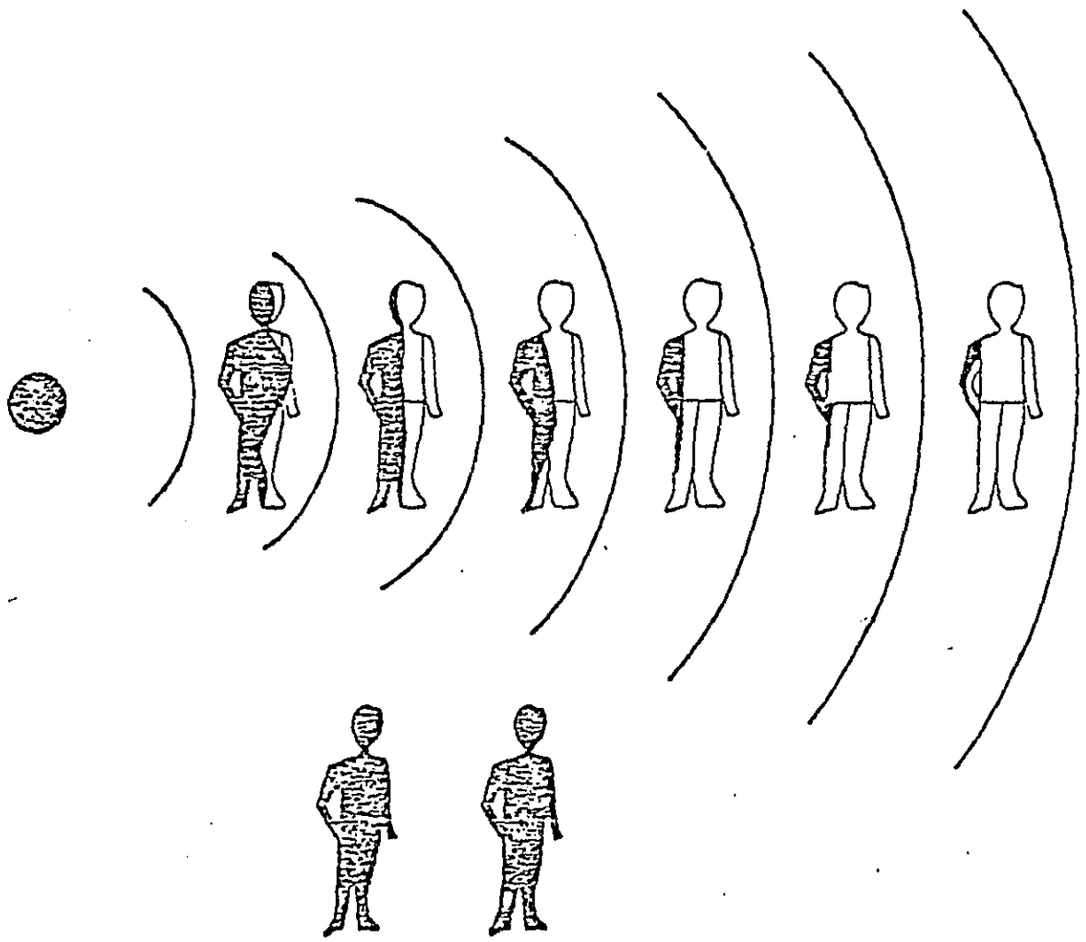
Each of the countermeasures is discussed in some detail in Section IV with its effectiveness, its cost, and the time required for it to become effective. It is important to note that, although the countermeasures are considered separately in this Manual, in the Strategic Guidelines, and in the NOIZOP computer program, they are indeed interconnected and interdependent. The planners of the noise control program should be aware of the interactions among the countermeasures in order to estimate their success. As examples, the cost and effectiveness of enforcing noise control laws against one source of vehicular noise makes enforcement against other vehicular noise considerably easier, more effective and less expensive; an education program benefits all other noise reduction countermeasures; if start up costs are considered, it is less expensive to pass a noise control code than to pass a set of individual laws concerning various sources; the adoption of a noise program in the planning and zoning process changes the future need for operational restrictions. The interactions cannot be stated in mathematical terms, but the planners should estimate them.

C. MEASURES OF EFFECTIVENESS

Before one prepares a plan, one should decide how the results are going to be evaluated. Frequently the selection of the measure of the effectiveness of a program determines much about the choice and the conduct of the program. In the case of community noise programs the three factors to be considered are the way that the noise is described, the way that the scarce resources are measured, and the way in which the time dimension is included. The use of scarce resources (money, personnel, equipment, real property) is adequately measured in dollars and the time dimension can be treated in terms of times it takes for a countermeasure to become effective and the duration of its effectiveness. The factor that is a problem is the noise descriptor. The various noise descriptors used by the EPA are described and discussed in Appendix. Briefly, the principal measure for noise levels in a community is the weighted, 24-hour average sound level in decibels, for which the symbol is L_{dn}. This descriptor includes additional weight for nighttime levels. The principal measure for the <u>impact</u> of noise levels is the Level Weighted Population (LWP), which is calculated by multiplying the number of people who are exposed to noise by the degree to which their exposure exceeds that which is considered to be harmless. Exhibit III-5 illustrates the concept that several people exposed to different amounts of noise are equivalent to a small number of people fully exposed to a high noise level. Some other descriptors are used in this Manual for occasional or sudden noises that disturb sleep or communications.

EXHIBIT III-5

LEVEL WEIGHTED POPULATION:
A METHOD TO ACCOUNT FOR THE EXTENT AND
SEVERITY OF NOISE IMPACT



IV. COST-BENEFIT FACTORS

A. SUMMARY TABLES

Exhibit IV-1 shows the relative effectiveness of the various countermeasures against each of the sources of community noise that is treated in this Manual. (The Strategy Guidelines document has some of the same information in Table III-2 on pages III-4 and III-5.) The entry in each cell of the matrix shows, on an ascending scale from 1 to 5, the estimated relative cost-effectiveness of that combination of countermeasure and noise source. A letter in the cell indicates the probable time which the countermeasure will take to become effective, starting with the day that the community decides to adopt a noise control program. The designation I, for immediate, is used only in those cases in which it is likely that the community can begin enforcing existing laws, such as nuisance laws, or can adopt policies by executive order, such as limiting the hours of use of community trash collection and park maintenance. Countermeasures for which the necessary implementation (including drafting and passing legislation, drawing up enforcement regulations, obtaining equipment, and training personnel) can be accomplished within a year are designated S, for short term. Countermeasures for which it will take one-to-three years for results to be significant are designated M, for medium term. Countermeasures with a still longer payoff are designated with an L, for long term.

The time factor is very important in preparing the noise control plan. Some administrations are interested only in those countermeasures that will show positive benefits within a few months or years; some administrations will want to coordinate the noise plan with the community's master planning schedule; some officials will want to wait for new technology or new sources of funds to make the programs more easily affordable; in some communities the growth rates of population, industry, or traffic may dominate the choice of countermeasures. The Strategy Guidelines document uses discounted costs in considering future budget years. The cost factors in this Manual can be applied year-by-year or they can be put in a multiyear plan and discounted if the planner so chooses. Wherever possible, the date of the cost quotation is given so that the planner can apply the appropriate price index to bring it to current dollars. The costs have been identified so that they are consistent with the cost codes used in the Strategy Guidelines document and thus can be used as inputs to NOIZOP.

Code: 1 to 5 means least effective to most effective;
I = immediate
S = short term
M = medium term
L = long term

	OPERATIONAL RESTRICTIONS										EQUIPMENT CODES		CONSTRUCTION CODES			OTHER					
	Nuisance Provisions	Source-Distance Noise Limits	Property Line Noise Limits	Animal Codes	Operational Style Controls	Location Limitations	Time Limitations	Duration Limitations	Maintenance	Retrofit	Product Regulations	Building Insulation	Barriers	Planning & Zoning	Compensation	Education	Complaint Response	Tax Incentives	Population Relocation
Domestic Noise Sources	4I											4L		2L		3M	4I		
Singing, shouting, whistling												4L							
Playgrounds, sports areas												3L							
Parties		2S				3S						4L							
Quarrels												4L							
Musical instruments		2M			4S	1S						4L							
Radios, TVs, phonographs		2M				4S						4L							
Model engines		3M			4S	4S						3L							
House and yard machinery	4M	4M		4S	4S	5S	5S					3L							
Air conditioners	3M	4M			2M			1M	3M	4M		4L							
Plumbing									3M			4L							
Pets			3M									3L							
Commercial Noise Sources	3I													4L		3M	3I	2M	
Alarms							4S		4M	5M									
Telephones		3S				4S	4S					4L							
Office machines	1M	2M			1S	3S	2S		2M	3M	4M	4L							
Elevators									2M	3M	4M	1L							
HVAC equipment	3M	4M							2M	3M		4L							
Refrigerator trucks	3S	3S			4S	5S	5S	5S	2M			3L							
Sound trucks	3S				4S	5S	5S	5S				3L							
Public address systems		4S				5S		4S				3L							
Rock concerts		2S				3S	3S					3L							
Discotheques, dance halls, bars		3S				4M	4S					4L							
Sports events		2S				3S	4S					3L							
Race tracks		3S				3S	4S					3L							
Industrial Noise Sources	2I													4L		4M	2I	2M	
Construction equipment	4M	2S		3S		4S		2M	3M			3L							
Agricultural equipment	1M	1S		1S		2S		1M	2M			3L							
Manufacturing equipment	4M	4S		4S		5M		3M	4M			3L							
Extractive equipment	3M	3S		3S		4M		2M	4M			3L			3M				
Transportation Noise Equipment														3L		2M	2I	2M	
Highway and expressway traffic								3M	3M			3L	3M		3M				
Street traffic								3M	3M			3L							
Motorcycles		3S						2M	2M			3L	3M						
Trucks		4S		2S				4M	4M			3L	2M						
Buses		4S		3S				4M	4M			3L	2M						
Sirens	4I			4I						5S		3L							
Horns				2S								3L							
Tire peeling	5I			4S								3L							
Revving up engines	5I		3S	3S			2S					3L							
Street cleaners		3S				4I		4M	4M			3L							
Snowplows		3S				4I		3M	3M			4L							
Fuel oil trucks		4S				4S		3M	4M			3L							
Garbage trucks	4I	3S				4I		3M	4M			3L							
Branch chippers	5I	4S				4I		4M	4M			3L							
Off-road vehicles	5I	2S			4S	4S		3M	3M			3L							
Snowmobiles		2S			4S	4S		3M	3M			4L							
Motorboats		3S			5S	4S		3M	3M			3L							
Rapid transit		1M						3M	3M			3L	4M	2M			2M	2M	
Railroads		1M						3M	2M			3L	4M	2M				2M	
Propeller airplanes												3L		2M				2M	
Jet airplanes												3L		2M				2M	
Helicopters												3L					2M		

Exhibit IV-1. Relative Effectiveness and Response Time for Various Countermeasures and Sources

JFA

Because personnel costs are applicable to all countermeasures, they are discussed in the next part. Then, the remaining parts of this section discuss each of the countermeasures (in their sequence as columns in Exhibit IV-1) and its applicability to the sources for which the table indicates that it is effective. Cost and effectiveness data are given wherever they are available, but in many cases they are only estimates.

The cost and effectiveness data that are contained in the Strategy Guidelines document have been repeated here; other data that were not available to the authors of that document have been collected and included. Where no data were available, the staff of Jack Faucett Associates has used experienced and informed opinion to make original estimates. In all cases the sources of the data have been identified so that the reader can consult the origins.

B. PERSONNEL COSTS

The cost to the community of the personnel needed to administer and to enforce a noise control program is the principal cost of most countermeasures. The unit cost of the community's employees is one of the easiest parts of the cost-effectiveness calculations. As an example, salaries paid to officials of a large (400,000 people) metropolitan government[1] in the Washington, D. C. area are as follows:

Supervisor of a noise abatement program	$20,000 - 30,000
Environmental officer,* health officer	14,000 - 21,000
Police officer (grade of private)	14,000 - 21,000
Building officer	13,000 - 19,000
Public information/citizen awareness officer	16,000 - 24,000
Instrument technician	13,000 - 19,000
Mechanic	12,000 - 18,000

Half of the annual cost of a police cruiser ($6,000 plus $0.35 per mile maintenance) is normally assigned to each police officer who is on enforcement duty. An overhead factor of 31 percent covers insurance benefits, administrative overhead, retirement, social security taxes, and out of pocket expenses.

---

[1] *Information supplied informally by Fairfax County, Virginia to Jack Faucett Associates, Inc. Nationwide averages for these costs have been requested from the National League of Cities, but they have not been received yet.*

* *The City of San Diego recently announced an opening for a deputy noise abatement officer at a salary range of $15,000 - 18,750 per annum.*

The numbers of people necessary to conduct, administer, and enforce a noise control program have been investigated.[1] The number of people clearly depends on the scope and nature of the program.

"Without exception, our investigation led us to the firm belief that there does not exist a purely typical noise program — anywhere."[2]

"The variances are evident upon acceptance of the spread in sophistication levels, priorities, resources, and a host of other factors including organizational placement."[3]

"... the end product is a program which ensures the staffing for a reduction of excessive noise levels within the community. There are twenty elements for a local community for a quiet community program (QCP). ... there are four steps in the process and five major program areas."[4]

	Major Program Areas				
Steps in the Process	Motor Vehicle	Property Line	Land Use	Construction Noise	Awareness Education
Problem Identification					
Strategy Development					
Law/Ordinance Enactment					
Enforcement/Maintenance					

This Manual treats all the countermeasures which are included in five major program areas cited, but largely ignores the start-up costs — the first three steps in the sequence. The costs of the fourth step, reasonable and continued enforcement of the legislation and maintenance of the program, are the costs on which this manual concentrates. This step "... calls for continuous monitoring of noise sources and

[1] *Hagan, W. F., Jr. et.al., "Task Analyses of Manpower Sampling for the Development of Program Models", E. H. White & Co., Inc., San Francisco, California (interim progress report), May 1979.*

[2] *Ibid, p. 4.*

[3] *Ibid, p. 5.*

[4] *Ibid, p. 10.*

updating of technologies. Coupled with an ever-ready posture ought to be a public participation/awareness/eduction program of a continuing nature in order to keep citizens informed as to program progress as well as to ensure that everyone understands the full implications of excessive noise. This activity also includes training for personnel engaged in the entire process".[1]

The authors of the report used two methods to estimate the staffing requirements for noise control programs. (1) They examined existing commuity noise programs, for all of which the directors indicated the degree to which their staffs were inadequate to do a good job, and scaled the staffs up to the needed size. (2) They analyzed the task descriptions of each positions and estimated the number of qualified people who would have to occupy these positions to fullfil the task needs.

A sample of the most successful and active commnity noise programs indicated that, if the projects were fully manned, and if the programs addressed all five parts of the noise program, the total personyears for the "core agency" for enforcement and program maintenance would be the following:[2]

City Population	From Sample	From Task Analysis
0 - 50,000	2.50	5.98
50,000 - 100,000	3.35	6.51
100,000 - 500,000	3.75	8.58
over - 500,000	8.75	10.40

From the task analysis it was concluded that these people should be allocated among the position descriptions approximately as follows:[3]

Positions Required	City Population (in thousands) 25-49	50-99	100-499	500 up
Noise Control Administrator	.77	.85	1.11	1.35
Assistant Noise Control Administrator	.53	.59	.77	.94
Noise Control Planner	.47	.52	.69	.83
Noise Control Specialist/Tech. 1	1.20	1.30	1.71	2.08
Noise Enforcement Officer	1.32	1.43	1.89	2.29
Noise Inspector	.60	.65	.86	1.04
Administration Assistant/Clerk Typist	1.07	1.17	1.54	1.87
Total	5.96	6.51	8.57	10.40

[1] *Ibid, p. 15.*

[2] *Ibid, p. 64.*

[3] *Ibid, pp. 78-84.*

The authors did not attempt to estimate the effectiveness of the programs for which the staff needs were calculated. The estimates are based upon experience in staffing organizations to fulfill a stated job requirement, but the requirement is not measured in terms of performance. It is assumed that each community will choose to pursue first the abatement of the sources which it feels are most objectionable and will subsequently turn to the others, presumeably when the first ones have been controlled effectively. In the discussions that follow of cost effectiveness for various countermeasures, the size of the noise program staff can be estimated only with great difficulty, for neither a good benefit measure nor a good effectiveness measure is available.

C. COST EFFECTIVENESS OF OPERATIONAL RESTRICTIONS[1]

1. Nuisance Prohibitions

Nuisance ordinances are the most subjective of noise control laws and usually are the easiest to implement because they only require the enforcement officers' "common sense". Because the concept of nuisance is relative, it can be a very difficult method of controling noise — especially if the noise is produced by popular sources (rock concerts) or established sources (industries). Three common types of nuisance ordinances are the following:

(1) Loud or Raucous Behavior Not Allowed

This type requires the officer to judge what is loud and raucous. Usually it is directed at persons and enforced by the police department because of the potentially dangerous situations that could exist. There is little opposition, especially by bystanders, to enforcement of this type of ordinance.

(2) Cannot Disturb the Peace

This type of ordinance is slightly more difficult to enforce because it covers more than human noises. Thus, what is disturbing to some may not be for others. Nevertheless, it is very popular and is used for parties, loud activities after normal hours, animal noises, and the like.

[1] *The first eight columns in Exhibit IV-1.*

(3) Cannot Make Unnecessary Noise

This type of ordinance is similar to those above except it gives the officer discretion when certain activities may be performed. It can be used to enforce against parties, defective equipment, and advertising activities.

Nuisance ordinances should not be denigrated, for they are very effective in some communities in which the population is basically law abiding and respectful of authority and the rights of others. Nuisance ordinances are valuable in situations in which sound level measurements are invalid because of high ambient levels, difficult weather conditions, or enclosed spaces. Impact and impulsive noise such as that from pile driving, blasting, and gun shots is difficult to measure without expensive equipment and may be so intermittant that an enforcing officer will have to wait a long time to measure an incident. Enforcing nuisance ordinances may be a useful alternative.

a. Domestic Noise Sources

When they are effective, nuisance ordinances are among the least expensive laws to enforce. Usually police officers perform the enforcement with no special training in noise control; thus, the whole patrol force is available. Persuasion is the most frequent method of imposing the sanctions of the community; usually the noise maker is told to cease or to reduce the noise immediately (as in the cases of loud parties or radios) or to stop very soon (as in the case of an alarm bell or repair work). Frequently the enforcement is not charged to a noise offense code, and data concerning such cases will be difficult to find in statistical records.

On the basis of several years' experience of working with police department that enforce noise control laws, Jack Faucett Associates estimates that enforcement by the police department of the noise aspects of nuisance ordinances in a city of 100,000 people at a level of activity that will persuade the population that the city is responsive will require the equivalent of between half a personyear and one personyear. There are no data from which to estimate the change in the L_{dn} which results from this level of enforcement of this sort of ordinance. An estimate based on experienced judgement is that the change will lie in the range of one-quarter to one-half a decibel for the entire community.

b. Commercial Noise Sources

Storefront loudspeakers, paging systems for automobile sales lots, loading and unloading activities, burglar alarms, and HVAC (heating, ventilating, and air conditioning) equipment are commercial sources against which nuisance ordinances frequently are enforced. Persuasion is the most common method, and the investigations are usually attributed to noise disturbances. In a city of 100,000 people the annual number of such investigations by the health, police, or environmental departments is small and less than one-quarter personyear is needed in a year to convince the citizens that the city is responsive to their complaints. The reduction in L_{dn} will be very small.

c. Industrial Noise Sources

Machinery noise, factory whistles, construction noise, blasting, and extraction noise are industrial sources against which nuisance ordinances frequently are enforced. Environmental or health officers typically do the enforcement, largely by persuasion or implied threats of injunctions. There is a close parallel between this sort of noise problem and that of noxious smells. A city of 100,000 is likely to have one or two cases of this sort per year and each is likely to require one or two weeks of investigation and discussion. One tenth of a person year is a reasonable estimate of the enforcement activity. The reduction in the L_{dn} in the immediate neighborhood of the source may be one-to-three decibels.

d. Transportation Noise Sources

Nuisance ordinances are frequently applied to unnecessary horn blowing; peeling of tires; exhibition speed; revving up and tuning engines; idling parked trucks, buses, and locomotives; running refrigerator units on parked trucks and trailers; and vehicles at construction sites. In the cases in which making noise is the objective of the activity and in the case of industrial and commercial vehicles, persusion often is ineffective and more serious methods are used. In a city of 100,000 an estimated equivalent of one police officer enforcing nuisance ordinances full time annually can reduce the L_{dn} by perhaps one decibel and produce against transportation sources the equivalent of a few percent reduction in the sleep disturbances and speech interference events. Such enforcement can reduce the fraction of the population that is exposed to L_{dn} in excess of 75dB by 15 percent.

2. Source-Distance Noise Limits

Most products that are regulated by source-distance limits are mobile; thus other kinds of limits are inappropraite or difficult to enforce. In some cases the test for exceeding the noise limit is audibility. "The noise (or sound) shall not be audible to a person with normal hearing at a distance of fifty feet," is a typical provision. Although the intention is clear, the lack of specificity makes such provisions easy to challenge. Most noise limits are defined in terms of a test condition and procedure that has been adopted by some group having standing in the field. "The sound level shall not exceed 83dB at a distance of 50 feet when measured in accordance with the method of Society of Automotive Engineers Standard J331a," is a typical statement.

a. Domestic Noise Sources

Consumer products may be labeled in terms of source-distance measurement. Lawnmowers, chain saws, electric power tools, through-the-wall air conditioners, and domestic appliances are the products most likely to require a Federally mandated label bearing a Noise Rating. This rating will show the sound level, in decibels, the product emits under stipulated conditions and the range, in decibels, of sound levels emitted by the same product made by other manufacturers. The lower the rating, the quieter the product will be. Communities may wish to enforce a regulation that all products required to have a label shall have that label intact when they are sold in the community. The effectiveness of such a regulation in a community can not be estimated until the nationwide effectiveness of the labeling regulations has been estimated. In general, the cost of enforceing such a regulation is low because only a few dealers will tamper with the labels.

Some communities may regulate the noise levels of house and garden machinery and through-the-wall air conditioners by applying source-distance critria of their own. In the case of a complaint, the enforcing officer must make the noise level measurements at the specified distance in accordance with an accepted standard or good technical practice. It is estimated that in a city of 100,000 there will be only a few complaints requiring these measurements each year, that the reduction in L_{dn} from the enforcement of such regulations will be negligible and that the cost of enforcement will only be a few persondays per year.

b. Commercial Noise Sources

Large HVAC equipment is commonly rated in terms of the noise levels at a given distance and these ratings are often included in the building codes of large cities. Building inspectors commonly review the specifications and the construction of new buildings to verify that equipment with the required noise rating is being used. After the building is finished, often there is no inspection to determine whether the equipment is quiet in operation. Exhibit IV-2 shows the source and severity of 16 commercial and high rise residential noise problems encountered in Chicago, Illinois and the nature, cost, and effectiveness of the noise control techniques that were adopted[1]. A recent EPA report[2] describes methods of estimating exterior sound levels produced by heating, ventilating, and airconditioning equipment mounted inside and outside of commercial, industrial, and multifamily residential buildings. The report also describes enforcement of this part of a building code through the use of a permit system. The annual cost of enforcing ARI (Air-Conditioning and Refrigration Institute) or other ratings in a city of 100,000 is about one personyear, for plan review and inspection, but the effectiveness in terms of L_{dn} reductions of these provisions cannot be estimated from available data.

Sound trucks and refrigeration trucks can be regulated effectively by source distance noise limits, especially if these limits are coupled to requirements for permits to operate such equipment. The permit can designate the number, locations, and times of use of the equipment and enforcement officers can measure the noise levels when the provisions of the permit are being met. Such enforcement will require only a few persondays per year. The limits on sound truck noise are frequently in terms of audibility at a stated distance. A reduction of 5-10dB in the sound levels in the immediate vicinity of sound trucks is a reasonable result of the enforcement. Reductions of 2-3dB in the vicinity of refreigeration trucks are a reasonable goal.

[1] *From testimony by the City of Chicago to the State of Illinois on noise legislation, 1972.*

[2] *Blazier, W.E., Jr.; D.A. Towers, and N.P. Miller, "Development of a Mechanical Equipment Noise Control Permit Scheme for Model Building Code," Bolt, Beraneh and Newman, Inc., Cambridge, MA, September 1977.*

Company Code No.	Noise Source	dB(A) Over Ord. (55 dB(A))	Solution for Problem	Cost	dB(A) Reduction
6	Grille exhaust fan	18	Wood barrier and plenum extension	$ 500	15
7	Rooftop refrig.	10	Sound barrier - 3-sided	433	backgrd.
10	Refrig. condenser	13	3-sided lined metal enclosure	786	"
12	AC compressor and cooling water	10	Enclosure and new pulleys and belts	650	"
13	AC cooling tower-roof	15	Sound barrier	500	"
19	Refer. compressor equipment	15	Wood enclosure and concrete block	2,000	13
22	AC cooling tower	11	Moved		backgrd.
25	AC cooling towers	20	3-sided lined enclosure	1,000	15
30	AC cooling tower	17	Acoustical enclosure	500	10
34	AC compressor	10	Moved a.c. and enclosed	500	backgrd.
41	Mechanical noise in power house - AC cooling tower	24	Not in compliance - Mufflers and enclosures installed		15
62	Refrigeration unit	16	Brick placed at rear of bldg. to enclose refrigeration units	1,200	down to 56 dB(A)
63	Exhaust fans & AC	11	Installation of sound barriers around air moving equipment	500	now 55 dB(A)
65	Air conditioner	20	Constructed 3-sided acoustically treated barrier around a.c. cooling towers	1,000	15
66	Air conditioner	24	Installation of sheet metal enclosure around induction and exhaust fans	500	15
67	Air conditioner	17	Addition of 16 duct silencers and reduction of fan speed	1,843	18

Exhibit IV-2: Cost of Noise Reduction for Commercial and High Rise Air Conditioning Equipment

c. Industrial Noise Sources

EPA is currently regulating portable air compressors using a source-distance noise limit (76 dB sound level at 7 meters). Regulations for tractors and pavement breakers used in the construction industry have been proposed, and these regulations have included source-distance noise limits. Communities may adopt ordinances that require all construction equipment used in the community shall meet the applicable Federal noise limits plus some factor for operational degradation, or the community may impose its own noise limits, especially on products that the Federal government does not regulate.

A recent report states that "88dB(A) is a reasonable noise level to expect used equipment with engines of 400 hp or less to meet. However, as the engine horsepower decreases, the noise level of 88dB(A) should similarly decrease."[1] These levels are those that would be measured at a distance of 50 feet horizontally from the equipment. To estimate the effect of imposing such a limit on the construction industry in a community requires that one estimate (1) the number of noise makers on site, (2) their distribution relative to the boundaries of site, (3) the duty cycle of each equipment, and (4) the number of construction hours in the year. These data are seldom available to local planners and building departments, but some plausible assumptions lead to an estimate of a 3dB reduction in the sound levels out to 1,600 feet from the boundaries of an urban building construction site. The reductions around shopping centers or a power plant site will be smaller and the reductions around a road or street through a built up area will be larger. Enforcement of such a noise limit reasonably could require one half a personyear in a city of 100,000.

Manufacturing and extractive machinery can be regulated by source-distance or property line noise limits. Mechanial equipment in industrial buildings usually resembles that in commercial buildings and the discussion in the previous section applies. Exhibit IV-3 shows the source and severity of 19 industrial noise problems encountered in Chicago, Illinois, and the nature, cost, and effectiveness of the noise control techniques that were adopted[2].

[1] *Toth, W. J., "Noise Abatement Techniques for Construction Equipment", Society of Automotive Engineers, Inc., Warrendale, Pennsylvania, August 1979, pp. 53-54.*

[2] *Ibid.*

Exhibit IV-3: Cost of Noise Reduction at Manufacturing Plants Under Noise Ordinance

Company Case No.	Noise Source	dB(A) Over Ord. (55 dB(A))	Solution for Problem	Cost	dB(A) Reduction
1	Worn gear	13	Worn gear replaced	$ 4,400	6
2	Spray booth exhaust fans	8	Commercial silencers	7,000	6
9	Rooftop spray booth exhaust fans	18	Commercial silencers	800	amb.
11	Pneumatic shaker	12	Conversion of pneumatic to electric shakers	5,000	amb.
15	Print presses	12	Moved	0	amb.
16	Steam relief valve	20	Shut off steam valve	0	amb.
18	Saws cutting plastic	18	Bricked in rear windows and new walls	5,000	amb.
20	Steam exhaust valve	43 @ 8K	Constructed wood enclosure	100	20
21	Cyclone dust collector	19	Reduced speed and added muffler	2,600	11
26	Exhaust fans and punch presses	9	Bricked rear windows and added silencers	5,000	amb.
42	Cutting machine	23	Closed windows	0	amb.
44	Exhaust fan	12	Removed equipment	0	amb.
45	Over all	20	3 yrs research and abatement program	165,359	
56	Air conditioner	15	Plenum type silencers	1,350	
57	Piggy-back unloader and refrig. units on truck trailers	12	Sound cabinet installed on diesel engine, sound barriers installed on pulley motors, vibrations isolators installed on springs, muffler installed to diesel exhaust, removed reefer trailers	33,950 plus $800 monthly maintenance	6
58	Exhaust fans on water spray booths	10	Silencers installed on rooftop exhaust fans	6,921	9
59	Exhaust fans	9	Bricked in 6 windows at rear of bldg. - Silencers over wall vents; muffler on spray booth exhaust fan.	5,000	amb.
60	Shearing press			300	amb.
61	Printing press	12	Print presses moved out of plant - windows closed on Kimberly Ave.	0	12

Some materials handling equipment used in industry and the equipment used in surface mining and quarrying resemble construction equipment and can be regulated in much the same way. Estimates of the cost and effectiveness are more difficult because the variations in the amount of heavy manufacturing industry and extractive industry among cities is very great. Each city will have to estimate its own reductions based upon the number and the size of the sites for which this countermeasure is applicable.

Agricultural noise is very hard to regulate because of the great mobility and short duty cycles of much of the equipment. Usually very few people are exposed. The Federal government and most State governments do not include agricultural equipment in the scope of their noise programs, and there is little precedent for its regulation. No estimates can be given for cost or effectiveness, but the methods used for estimating these quantities for construction equipment noise seem most closely applicable.

d. Transportation Noise Sources

Aside from the equipment requirement for mufflers, the source-distance noise limit is the most common method for regulating the noise from motor vehicles. Some ordinances say that the noise "shall not be audible at 100 feet", but most motor vehicle codes require measurement with a sound level meter. Radios in motor vehicles, however, are effectively regulated on the basis of audibility at a given distance, because the enforcing officer seldom has time to make noise measurements of the noise from radios. If he is farther away than the permitted distance and he hears the radio, a violation exists by definition.

Appendix B of the Strategy Guidelines document gives some information on a computer program which computes the decibel reduction which results from regulating the noise of all sources of a given type. EPA uses a National Roadway Traffic Noise Exposure Model[1] for similar purposes. This model simulates the noise generated by vehicle operations on the 3,586 million miles of the national roadway network, which serves about 217 million people. The model accepts differences over the years in vehicle noise emissions, vehicle operation characteristics, roadway and traffic flow factors, and populations and population densities. The model predicts both L_{dn} and LWP. It also predicts single event statistics including indoor speech interference and sleep disruptions.

[1] *"National Roadway Traffic Exposure Model", EPA, July 1979.*

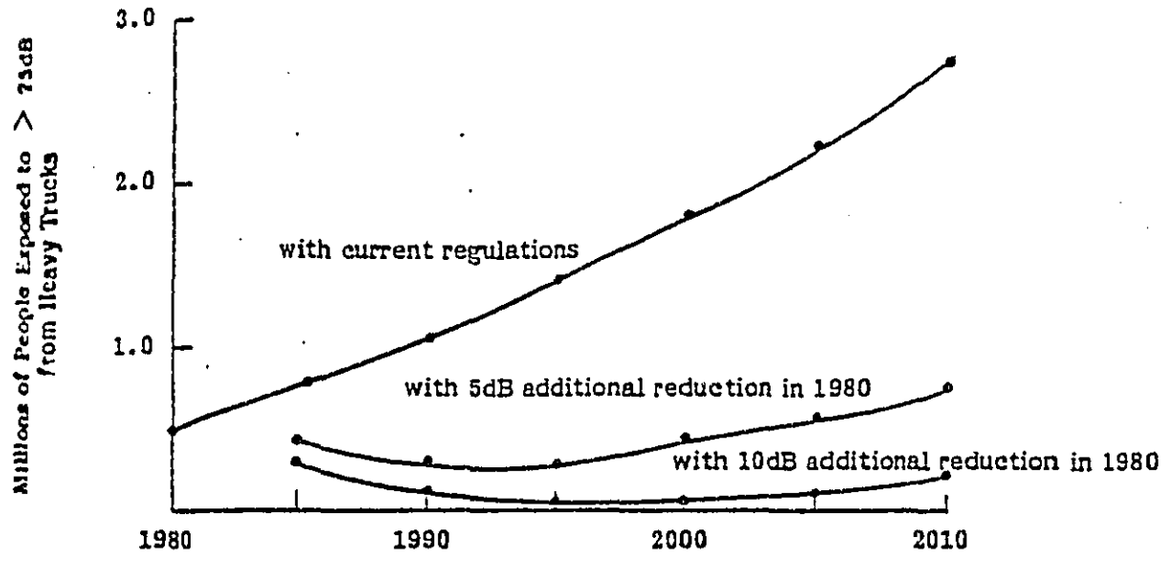
The results of simulations using that model that are given in this document are nationwide results. To the extent that a particular community is not representative of the national situation, the results presented here may not be accurate. However, even though a city of 100,000 people represents less than one-twentieth of one percent of the national population, the relative change in the traffic noise is likely to be reasonably estimated by scaling down the national data.

For example, Exhibit IV-4 shows the effect of changes in the regulations for heavy trucks. A reduction in 1980 of 5dB in the permissible noise level will, by 1999, have reduced the number of people who are exposed to an L_{dn} of 75dB or higher from almost 2 million to less than half a million. A 10dB reduction would reduce this number of people to less than one hundred thousand. The same reductions of 5 and 10dB in 1980 will reduce the number of people exposed to L_{dn} of 65dB or more from about 20 million to about 7 and 5 million, respectively.

State and local governments have considerable freedom in passing and enforcing laws regulating noise from motor vehicles in operation on streets and highways. Most Federal regulations concerning vehicular noise apply only to new products at the time they are offered for sale. One Federal noise regulation applies to interstate motor carriers when they are in operation on the highway, but only about 28 percent of the trucks in the nation are affected. State and local governments can pass and enforce their own laws limiting the noise from other trucks, automobiles, and motorcycles when they are in operation. A local government might estimate that enforcement of an operational regulation that is 5dB more stringent than current U.S. Department of Transportation regulations would reduce the exposure of the community's citizens to L_{dn} in excess of 65dB by 60-70 percent.

Exhibits IV-5, 6, and 7 shows the reductions in the number of single event disturbances that result from changes in the regulations in the noise limits for various classes of vehicles at the time of sale. The eight chart graphs shown in Exhibits IV-5 and IV-6 show the reductions in the number of sleep disturbances and of speech interferences nationwide as a function of regulatory level for four different classes of vehicles.

The data from which these graphs were plotted includes the assumption that State and local government enforce operational use of the vehicles to ensure that a large fraction of them retain the low noise level they had at the time of their sale. Note that the scales are different for the various vehicle types; the number of events caused by buses



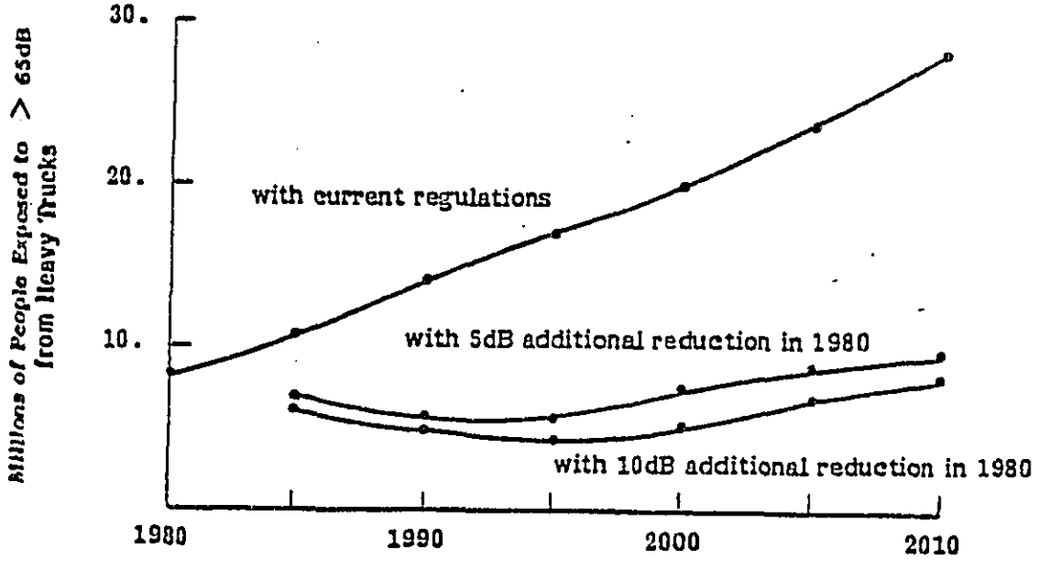
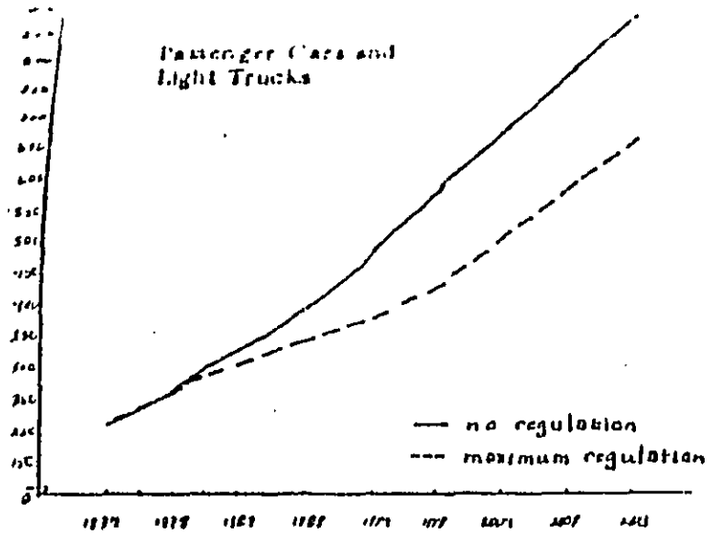
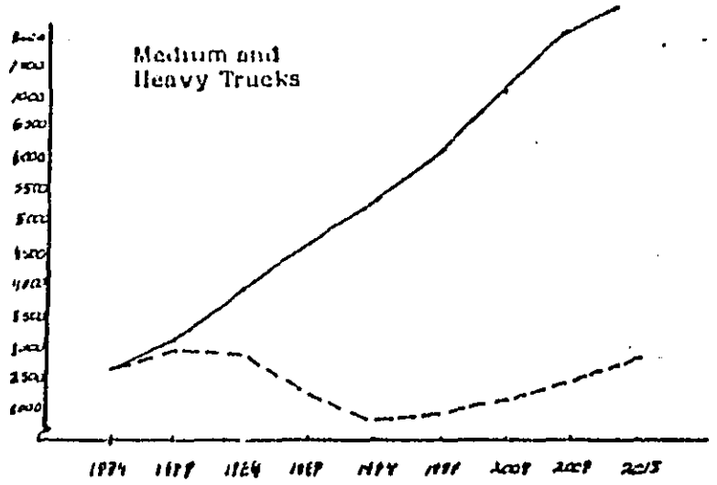
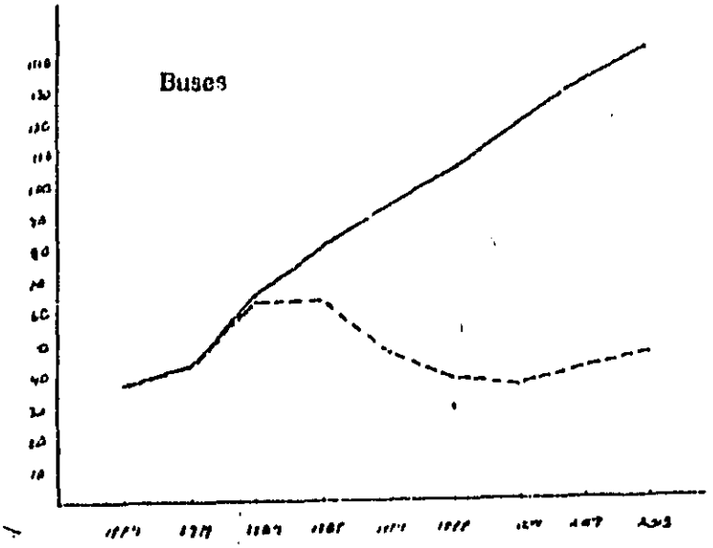


EXHIBIT IV-4: HEAVY TRUCK NOISE EFFECTS

JFA







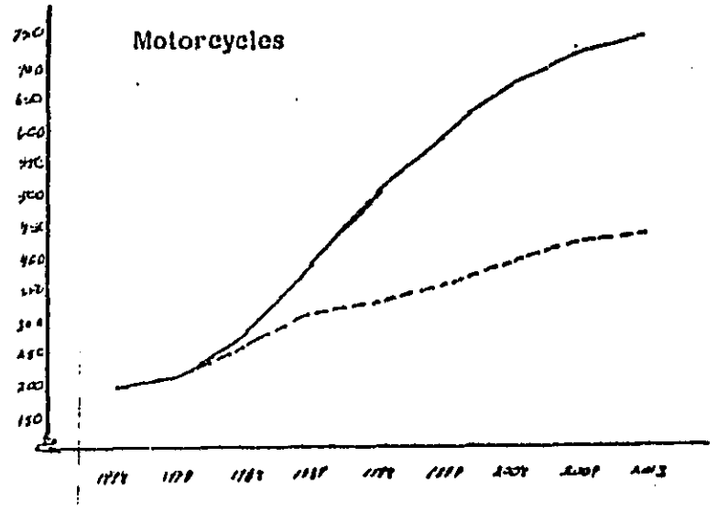
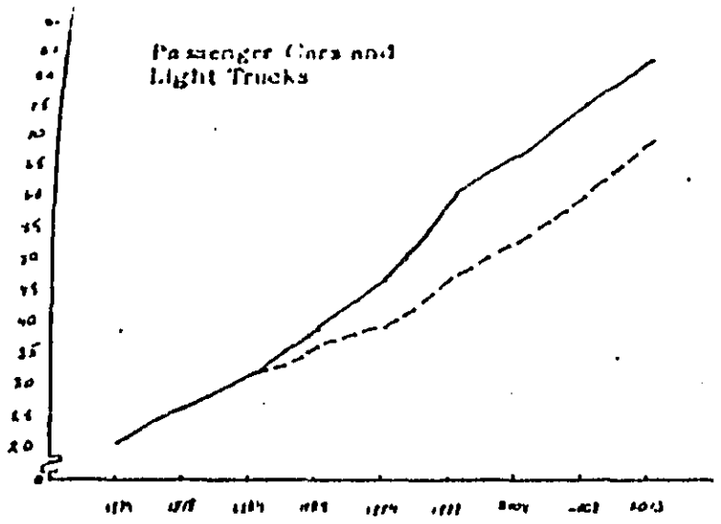
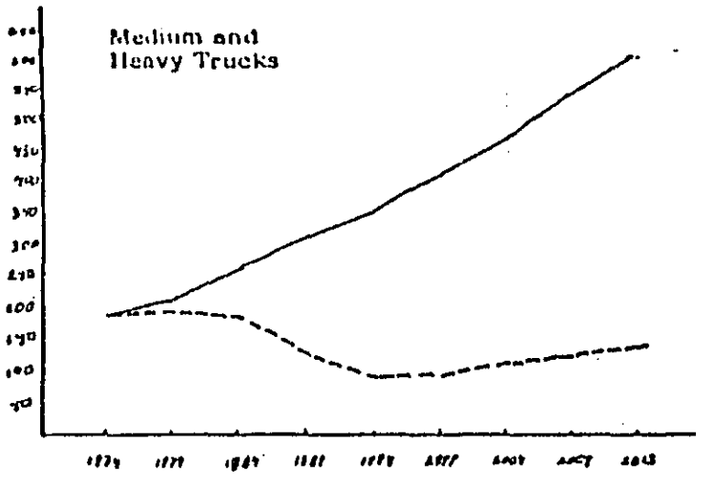
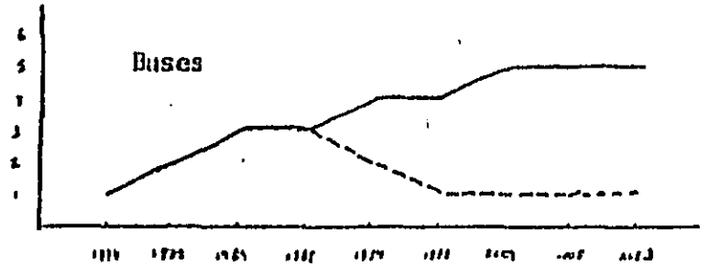


EXHIBIT IV-5: MILLIONS OF SLEEP DISRUPTION EVENTS







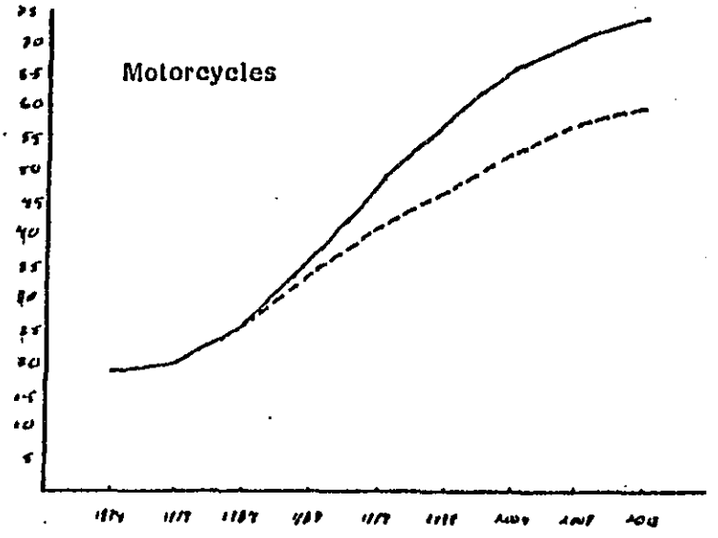
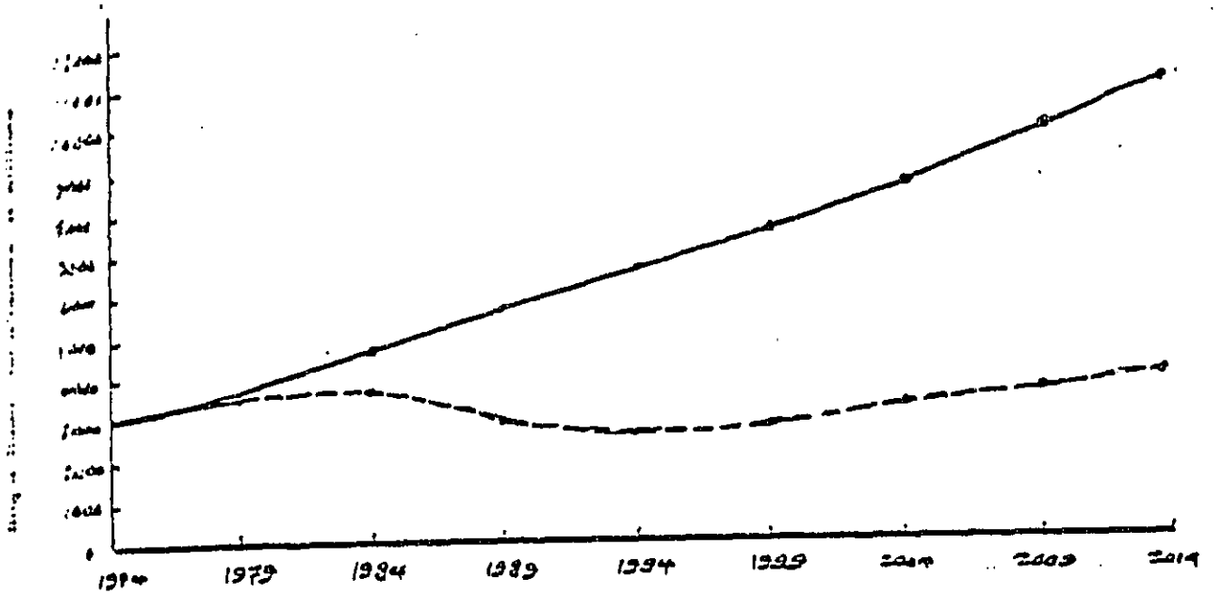
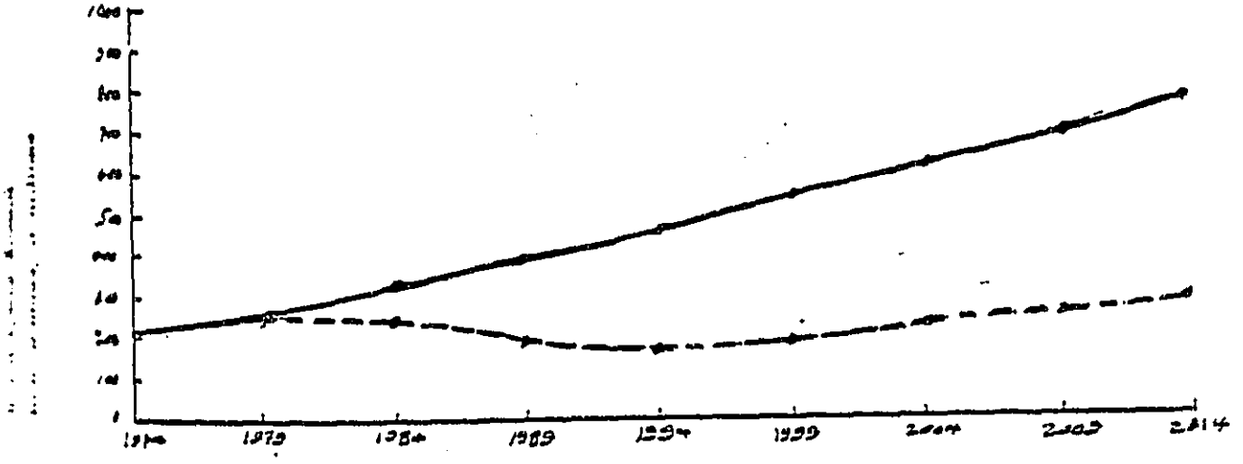


EXHIBIT IV-6: MILLIONS OF SPEECH INTERFERENCE EVENTS



Sleep Disturbance From All Vehicle Classes



Speech Interference From All Vehicle Classes

EXHIBIT IV-7: SUMMARY CURVES FOR SLEEP AND SPEECH EFFECTS

JFA

would barely show on the bottom of the graph for heavy trucks. Note also that the statistics, using the single events measure, allow addition of the number of sleep disturbances and the number of speech interferences for each of the vehicle types. Exhibit IV-7 shows the sum of the single events for all the vehicle classes with different regulations for each class.

On the graphs for passenger cars and light trucks, the solid curve represents the situation in which these vehicles are unregulated and continue to have noise levels unchanged from their 1978 values. The dashed line represents the situation if there is a regulated noise reduction of approximately 4dB effective beginning in 1987.

On the graphs for medium and heavy trucks the solid curve represents the situation in which all newly sold medium and heavy trucks have their noise levels (in an acceleration test) regulated at 83dB from 1978 through 1981 and at 80dB beginning in 1982. The dotted line assumes that a further reduction to 75dB is effective in 1985.

On the graphs for buses the solid curve assumes that all buses are unregulated, and that their level (in an acceleration test) is about 87dB. The dashed line is for the case in which noise limits (in an acceleration test) are set at 83dB beginning in 1983, 80dB beginning in 1986, 77dB beginning in 1988, and 75dB beginning in 1990.

On the graphs for motorcycles the solid curve represents the case in which motorcycles are unregulated and have an average noise level (in an acceleration test) of about 85dB. The dashed curve represents the case in which the noise level (measured in an acceleration test) is limited to 83dB in 1983, 80dB in 1986, and 78dB in 1990.

Data such as these probably can be scaled down for use in estimating the effectiveness of reductions in the noise levels of particular classes of motor vehicles. The cost of achieving a particular level of reduction is dependent upon the size of the community and the number of out-of-community vehicles that help create the noise problem. In San Francisco four police officers wrote more than 12,000 citations for noise violations in a four-year period (in one year the number exceeded 4,000) . . . the average level or L_{eq} in the major business areas of the city decreased 3dBA since the inception of noise control."[1] The police noted that the number of resident violators dropped so much at

[1] Bodisco, R. G., *"Traffic Noise Abatement", Proceeding of Inter-Noise 78, Noise Control Foundation, Poughkeepsie, New York, p. 863.*

the sites at which they regularly enforced that new sites had to be chosen. However, there were few resident violators at the new sites as well, so the police department concluded that the program was effective in causing San Francisco residents to replace defective mufflers and to refrain from installing nonstandard exhaust equipment. If the police stopped enforcing in a neighborhood, it took about six months for the number of violators to return to its previous level. Intensive enforcement at a site every three months kept the noise levels relatively low. The program now uses two officers essentially full time for noise enforcement duty.[1]

In Boulder, Colorado a municipal ordinance specified allowable levels for both vehicular and nonvehicular sources.

> "Allowable noise levels between 7:00 A.M. and 11:00 P.M. are 55 decibels for residential areas, 65 decibels for commercial areas, and 80 decibels for industrial areas. Monitoring for this program is handled by a team of three officers operating about 20 hours a week in a specially equipped and marked car. Their salaries and the cost of the equipment for this effort come out of a modest $36,000 budget."[2]

The cost of in-use enforcement of local noise control laws against motorcycles have been estimated, on a national basis and are shown in Exhibit IV-8.[3] "Enforcement effectiveness varies widely in California. Counties with strong penalties, visual posting, and systematic enforcement tend to achieve good results. Such a program can cut exhaust modification in half."[2]

Currently, the EPA is sponsoring an investigation of the cost and effectiveness of source-distance law enforcement against trucks and motorcycles in several communities. When these data have been collected, they will be included in this Manual.

Railroad cars and locomotives are regulated on the basis of source-distance criteria. These are discussed with other railroad equipment in Section 3d.

---

[1] *Badisco, R.G., personal interviews.*

[2] *"State and Local Noise Control Activities 1977-1978", EPA (draft) May 1979, p. 3-13.*

[3] *Letter from Robert Stone of Technology + Economics, Inc., Cambridge, Massachusetts to Dr. Kurt Askin, EPA, 27 August 1979, Appendix C.*

[4] *Ibid, p. 3.*

Appendix C: In-Use Enforcement Costs

I.	Equipment Costs	
	50,000 enforcement officers (nationally) times 1 instrument per 10 officers	5,000
	Cost per sound meter	$1,000
		$5,000
II.	Training Costs	
	50,000 enforcement officials (nationally) times 1/2 day per official	25,000
	Cost per day	160
		$4,000
III.	Enforcement Labor Costs	
	20 percent of registered vehicles (4,900) stopped	980
	6 minutes per vehicle[1] times $20/60 per minute	$ 2
		$1,960
	Total national costs	$10,960

[1] Does not include court time.

EXHIBIT IV-8: IN-USE ENFORCEMENT COSTS FOR MOTORCYCLES

3. Property Line Noise Limits

A common and effective ordinance to control noise from stationary sources is a numerical limit on the noise at the boundary of the receiving or (less commonly) of the emanating property. In either case a sound level measurement is made and the results are compared with the noise limit. Weather conditions must permit valid measurements and the enforcement officer must obtain the permission of the owner of the property on which the measurements are made. Frequently the noise limits are stated in terms of receiving land use and time of day, i.e. "It shall be an offense to create or to cause to be created at or within the real property boundary of a receiving land use sound levels which exceed the following maximum permissible sound levels:

Receiving property in a Residential Zone (R-1 to R-8)
daytime 65 dB
nighttime 50 dB
Receiving property in a Commercial Zone (C-1 to C-4 and U-1)
at all times 65 dB
Receiving property in an Industrial Zone (M-1 to M-3)
at all times 75 dB
Noise Sensitive Area
at all times 50 dB"

4. Domestic Noise Sources

Air conditioning equipment is the most common source of complaints against noise that exceeds property line limits. Through-the-wall and, especially central units are frequently closer to the bedrooms and living rooms of adjacent homes than they are to the equivalent spaces in the property they are cooling. Building officers are well suited to enforcement of the law in such cases.

Other sources of complaints are garden equipment, workshop tools, radios, television receivers, phonographs, musical instruments, tuning and revving motor vehicles, model airplanes and boats, and parties. Many of these activities are intermittant and the investigating officer must arrive promptly if he is to be sure that he measures the same thing that the complainant reported. The police are often asked to investigate such complaints, but some other department of the community government may have to make the measurements. Therefore, nuisance laws are frequently used instead.

c. Commercial Noise Sources

Loudspeaker systems on storefronts or in parking lots; refrigerator trucks; noise from bars, discotheques, and restaurants; rock concerts; motor racing and other sports events; and heating, ventilating, and air conditioning equipment all are sources of complaints about noise which exceeds the limits at the property line. Many of these sources are reasonably consistent from day to day and the enforcing officer can respond to the complaint on his schedule. Rock concerts and sporting events have to be anticipated and the measurement personnel and equipment have to be in place and ready to respond to complaints.

d. Industrial Noise Sources

Materials handling equipment, regular industrial operations, construction equipment, and loading and unloading activities are frequent sources for which complaints are filed. Such sources can be investigated on the enforcing officer's schedule. Sometimes the remedies are expensive and the enforcement by persuasion or by legal action may be time consuming.

e. Transportation Noise Sources

Some communities use property line restrictions to limit the noise from idling vehicles such as trucks and buses that need long warm-up times or that need auxiliary starters. Other communities successfully apply these restrictions to off-road recreational vehicles and to motor boats where such sources are problems.

The proposed EPA noise emission standard for railroad facilities and equipment is a property line standard and the standard for locomotives and cars is a source-distance standard. Railroad noise is or will be Federally regulated. Local laws cannot be enforced if they differ from the Federal regulations in their limits. Therefore, although the noise limits are still subject to some controversy, it seems prudent for the community to assume that the existing and proposed noise limits for railroad vehicles, yards, and facilities and equipment will be the maximum that exist in the period for which the community is planning a noise control program. These limits are as follows:

Stationary Locomotives: 70dB at 100 feet when idling, 87dB overall maximum

Moving Locomotives: 90dB at 100 feet overall maximum

Moving Cars: 88dB at 100 feet at speeds equal to or less than 45 mph
93dB at 100 feet at speed greater than 45 mph

Facilities:

From 1 January 1982 and all facilities and equipment 70dB L_{dn} for a 24-hour period on or beyond a railroad yard boundary line

From 1 January 1982, all facilities and equipment, 70dB L_{dn} for a 24-hour period and 84dB L_{eq} for a one-hour period on or beyond a railroad yard boundary line

From 1 January 1985, hump yard facilities and equipment, 65dB L_{dn} for a 24-hour period and 79dB L_{dn} for a 1-hour period on or beyond a railroad yard boundary line

From 1 January 1982, car retarder, 90dB at 30 meters

From 1 January 1982, stationary refrigerator cars, 78dB at 7 meters

From 1 January 1982, car coupling, 95dB at 30 meters

Enforcement of property line noise limits is almost always only in response to complaints or request for investigation. Building and health officers, environmental specialists, and the police are used to enforcing such limits, but usually only the police respond 24 hours a day every day. Some jurisdictions assign enforcement and investigations to the police only in the hours in which the other departments are not on duty. Cost of enforcement are therefore difficult to calculate.

In general, experience has shown that almost every investigation that reveals a violation results in abatement to the extent that the violation no longer exists. Either the source is discontinued or it is quieted. A rough estimate is that one noise control specialists can investigate and cause to be corrected all reported property line violations in a city of 100,000 and still have time for some educational and public awareness activities.

4. Animal Codes

a. Domestic Noise Sources

Noise from dogs, roosters, birds, cats, and occassionally other animals is a far greater source of complaints than is their contribution to the average noise level in the level in the community. Exhibit IV-9 shows a compilation of the sources of complaints in several communities. In most of the communities that included this classification, animal noise was the most frequently cited cause for complaints.

An effective measure used by some communities is to enforce a rule that, after the third complaint, the animal will be removed from its owner and treated as the animal control program officer sees fit. EPA recently published publication control measures for barking dogs.[1]

Exhibit IV-10 shows a tabulation of the measures that various communities have taken to deal with animal complaints (mostly barking dogs). The tabulation includes estimates of the cost per animal case where it was available. The number of decibels by which the noise level will be reduced can not be calculated from these data or other available data, but it can be estimated that one full time animal control officer can handle a few hundred cases per year and that the average cost per case is likely to be in the vicinity of $50.

b. Commercial Noise Sources

Most communities that enforce noise control laws which apply to commercial dog breeders, kennels, and veterinary hospitals, apply property line standards just as they do with other commercial noise sources.

5. Operational Mode Restrictions

a. Domestic Noise Sources

Garden and yard maintenance equipment can be required to be operated with all noise control equipment provided by the manufacturer in place and in good working order. Swimming pool pumps, heat pumps, air conditioners, and similar equipment can be required to be operated with all shields and enclosures provided upon installation in place and in good repair.

[1] *"Quiet-Man's Best Friend" EPA.*

Noise Source	Bloomington Minnesota	St. Louis County Missouri	Hillsborough County Florida	Toronto Ontario	Colorado Springs Colorado	San Diego California	Palo Alto California	Allentown[1] Pennsylvania	Pittsburgh[2] Pennsylvania	San Francisco[3] California
Truck-Mounted Solid Waste Compactors and Refuse Collection	14	21		5	7	2		8		32
Street and Highway Traffic	9		2	3	7		12	59	74	64
Construction	4	11	2	15	4	2	9		2	23
Loading and Unloading Delivery Trucks			1	5						
Refrigeration Units			1							
Motorcycles			7		23	1		12		55
Aircraft and Airports			3		1			16		28
Recreational Vehicles			7							50
Emergency Vehicles			1					10		32
Trains			1		1				1	9
Air Conditioning	5	11	8	13						
Music			7	13	7	5	17			
Industrial Noise	13	24	24	4					3	11
Trucks			4		3			8		31
Household Equipment	6		5					5		29
Animals	29		1	20	4	66	43			33
Neighborhood[3]			1	1				67	10	
Public Events		4	16		4			5		
Buses										20
Miscellaneous[4]	20	29	7	20	34					5

NOTES: 1. Percent citing a specific noise source.
2. Percent of locations where source is major cause of noise.
3. Includes voices, children; but not traffic or mechanical sources.
4. No sources sited in less than one community included under this heading.

EXHIBIT IV-9: Percentages of Complaints About Noise From Various Sources

EXHIBIT IV:10

MEASURES FOR DEALING WITH ANIMAL NOISE COMPLAINTS (1979)

	Honolulu, Hawaii	Alexandria, Virginia	Montgomery County, MD	Toronto, Ontario	Colorado Springs, Colorado	San Diego, California	Washington, D.C.	Fairfax City, Virginia	Prince Georges County, MD.	Bloomington, Minnesota	Hillsborough City., Florida	Palo Alto California
plaint Form Available						x[4]						
plaint Registered	x	x	x	x	x	x	x	x	\	x	x	x
ter to Owner	x		x	x	x	x	x		\	x	x[8]	
ding Brochure to Owner	x	x	x				x			x		
gestion of Cause	x	x	x	x	x							x
l Investigation	x	x	x		x[3]	x		x		x[2]		x
l Demonstration	x	x				x						
ow-Up Call/Visit		x	x			x						
al Action	x	x	x	x	x	x		x	x	x	x	x
rral to Obedience School		x	x				x[5]			x		x
ncy Operated School		Seldom										
tures/Demonstrations for Owners												
of Humal Collars	Seldom					Rentals						
of Water Spray	Pamphlet	x				x		Pamphlet		x		x[9]
plaints Received By	EPA/HS[1]	A.C.	A.C.	NCG	Police	ONAC	Dog Pound	ZI	A.C.	x[6]	ENC	A.C/Police
ulation Enforced By	HS	A.C.	A.C.	Police	Police	ONAC:/Police	Police	ZI,Police,A.C.	A.C./Police	x[6]	EPC	Police
ining of Personnel	1WK OJT[2]	90 Days	90 Days	None		OTJ	None	None	None	MS[7]		A.C.
get	N/A	$180K	$14.4K	N/A	$60K	$104.1K	None	N/A	$30K	$50K	$14K	$87K
ber of Staff	20Ft, 8pt	11	1/2	N/A	4	5	None	N/A	2Ft 2pt	35ft clerical	4	3ft clerical
ber of Man Hours per Week	N/A	N/A	20-25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28	4-5
ber of Cases per Year (Est.)	1000	1400	250	300	60	1095	N/A	200	N/A	100	1	185
t per Case (Est)	N/A	N/A	$58.00	N/A	$43.00	$45	N/A	N/A	N/A	N/A	$18	N/A

1) EPA Environmental Protection Agency
HS Humane Society
AC Animal Control
NCG Noise Control Group
ONAC Office of Noise Abatement and Control
EPC Environmental Protection Commission
ZI Zoning Inspector

2) OJT On-the-job training

3) Only after second complaint

4) Complaint forms available at public libraries as a preliminary, unofficial gesture towards enforcement.

5) Only unofficially

6) Department of Community Development, Building and Environmental Division.

7) Most Inspectors have MS in Environmental Science

8) Notified by telephone.

9) Only if recurring problem.

b. Commercial Noise Sources

All heating, ventilating, and air conditioning equipment can be required to be operated with all the noise reducing equipment which was provided at installation in place and in good working order. Sound systems at places of entertainment can be required to be operated at amplifier settings that have been approved by the noise control authorities. A similar requirement can be set on multispeed fans and ventilation systems.

c. Industrial Noise Sources

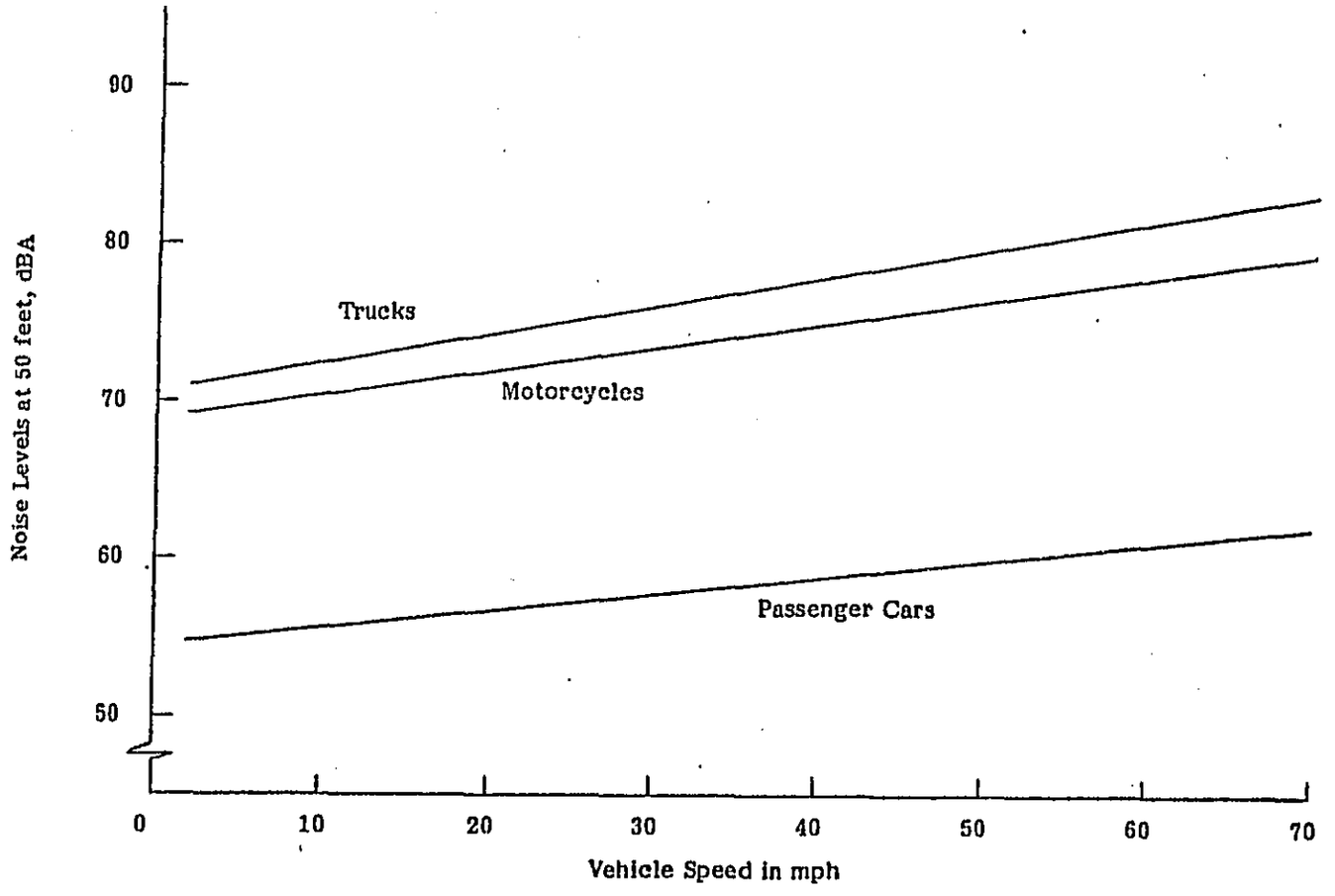
Industrial equipment may be required to be operated far within its operational capability in order to reduce noise from impact, gear boxes, or escaping steam.

A local ordinance may require industrial and construction equipment to be operated with all the manufacturer's noise reducing equipment installed, in operation, and in good repair. This requirement is very effective in controlling noise from construction equipment, e.g. air compressors, which frequently are operated with the enclosure doors open, and tractors, from which the mufflers frequently are removed.

d. Transportation Noise Sources

The local law may require that motorcycles and other motor vehicles be operated in the highest gear suitable for the speed, load, and grade. "Exhibition speed", tire peeling, and unnecessary acceleration may be prohibited. Speed restrictions may be placed on motor vehicles, although the effectiveness of speed controls on noise levels is debated.

Exhibit IV-11 shows the relationships between noise level and speed that were measured in a year-long program of measurement of motor vehicle noise in Florida. Contrary to popular assumption, the noise levels of trucks changed more with speed than that of passenger cars. The data given in the Strategy Guidelines document are more common expectations and are reproduced below.



Source: Yost, William A., "Noise Levels from 20,000 Motor Vehicles", presented at NoiseXpo 79, Chicago, Ill., 5 April 1979.

EXHIBIT IV-11: Relationship Between Vehicle Speed and Noise Level

Default Values in dB To Be Used in Estimating
Present Noise Levels of Selected Sources

	Existing Population, Typical Operating Conditions			
	Low Speed (Urban Street)		High Speed (Highway)	
Source	Mean	σ	Mean	σ
Trucks	85.0	3.7	85.5	3.5
Autos	65.0	3.7	75.0	3.5
Motorcycles	76.0	2.9	80.6	2.8

σ = standard deviation

Speed restrictions on trains may be effective, but slower trains prolong the noise exposure and block grade crossings for longer periods and such disadvantages may be more important than the noise level reductions. Sirens on emergency vehicles may be an important source of noise in the community, and operational controls that limit the use of sirens to a safe minimum may be very useful. The sirens seldom are important contributors to overall, long term noise levels, but they are important sources of single event disruptions.

Aircraft taxi and flight patterns are operational controls, and frequently the community can influence the decisions of the Department of Defense and the Federal Aviation Authority in their selections of safe approach and departure flight paths. If the airport traffic is not controlled by the FAA, the community can regulate the paths itself. Most airports are municipally owned and the community can control some of the ground operations.

Operational controls are among the most cost effective measures available to a community because the cost of enforcement is low. Whenever such measures are effective, this countermeasure will be a desirable one. Simple inspection by enforcement officers untrained in special noise control techniques is sufficient to enforce these sorts of restrictions in most cases. Usually the costs of adding enforcement of such provisions to the health, environment, and police departments' duties is negligible, and the reduction in noise is significant.

6. Location Limitations

a. Domestic Noise Sources

Some communities set aside parks or open areas for noisy activities such as flying model airplanes or sailing model motorboats. Rifle, pistol, skeet, and trapshooting activities are similarly restricted. Other communities restrict the places in which groups may have out-of-door religious services or public speakers or concerts. Chain saws may be confined to the area in which the fallen trees are found instead of back yards.

b. Commercial Noise Sources

Quiet zones may be located around hospitals, nursing homes, schools, convents, and wildlife sanctuaries. Zoning is a form of location control. Commercial operations may be restricted on the sides of property that abut property in zones classified for residential use. Refrigerator trucks may be required to park away from residences.

c. Industrial Noise Sources

Zoning provides the chief form of limitation on the locations of industrial operations. Quarrying, surface mining, and construction may be prescribed for certain locations because of the noise that will result. Such restrictions usually are imposed through the permit system that most communities have.

d. Transportation Noise Sources

Rerouting traffic, especially trucks, is the most important form of location limitation for motor vehicles. Locomotives, buses, and trucks may be prevented from idling in particular locations. Recreational off-road vehicles may have their operation confined to particular open spaces. Snowmobiles, motorcycles, motorboats, and competitive automobiles frequently are confined to designated areas where the noise will not interfer with quiet activities.

Enforcement of location limitations also is a cost-effective countermeasure for the sources to which it applies. As is the case with operational use controls, enforcement is easily added to existing duties. The creation of quiet zones and the restriction of truck traffic to designated routes are the most effective techniques, but the degree of effectiveness depends upon the degree to which these are problems in the particular community.

7. Time Limitations

a. Domestic Noise Sources

Time restrictions are commonly placed upon the operation of house and garden tools, of musical instruments, and of amplified sound. The restrictions are likely to be designated for nighttime and the Sabbath. Nighttime restrictions favor the majority of the population who sleep at night, and the greater the differential between nighttime and daytime noise limits, the greater the bias against nighttime workers, invalids, and others who sleep in the day. The choice of the Sabbath depends upon the religious composition of the community.

b. Commercial Noise Sources

Restrictions on the hours of loading and unloading, on trash compaction operations, and on the use of amplified sound in advertising all are common examples of time restrictions on commercial operations. Race tracks, sporting events, bars, discotheques, and cafes may have their hour of operation listed for reasons of noise. Fireworks displays, parades, political rallies, parties with amplified sound and similar noisy events can be controlled by a system of permits.

c. Industrial Noise Sources

Construction activities are commonly limited to starting times and in hours of operation. Extractive industrial operations, especially blasting, usually are limited in their hours if the operations are close to residences.

d. Transportation Noise Sources

Airport operations and trash collection vehicles are the most commonly time regulated transportation activities. Subway and railroad operations may be limited by noise considerations. Operations of off-road recreational vehicles may be restricted in both times and locations of operation. Municipal vehicles such as street sweepers and tree maintenance trucks may be restricted in the hours of use.

Time restrictions are like location restrictions in that they are easy for any enforcement officer to enforce without special training or equipment. They are among the most cost-effective of all countermeasures.

8. Duration Limitations

a. Domestic Noise Sources

Restrictions are seldom placed on the duration of operation of domestic equipment; usually the hours of operation are controlled.

b. Commercial Noise Source

Burglar alarms are a frequent target for duration limits. It is common to require that the police or fire department be able to shut them off or that they cease operation automatically after a certain number of minutes of ringing (enough to have attracted a response). The duration of the testing of emergency sirens is frequently limited. Some communities limit the duration of church bells and carillon concerts.

c. Industrial Noise Sources

Duration restrictions are uncommon in industrial operations unless there are unusual circumstances such as pile driving near a quiet zone, in which case a permit may limit the operations to a few hours per day.

d. Transportation Noise Sources

Duration of idling of locomotives, trucks, and buses sometimes is limited by ordinance. There are few other applications for this kind of restriction to transportation vehicles.

This kind of restriction is very cost-effective in the few cases to which it is applicable. Burglar alarms are the most common application, and these devices contribute significantly to noise levels in their vicinity if they are allowed to operate for a whole night or weekend.

D. EQUIPMENT CODES*

1. Maintenance

a. Domestic Noise Source

One of the frequent reasons for noisy equipment is lack of proper maintenance. Often lubrication is all that is needed to reduce the noise from fans, air conditioners, etc. Attention to required maintenace can alleviate many problems and the skills required to accomplish this range from a "backyard mechanic" to a skilled technician.

Degradation of equipment is closely coupled with lack of maintenance. Thus, replacing defective mufflers on lawn mowers, chain saws and other construction equipment can improve the noise climate considerably.

Existing noise control measures also can degrade through the development of cracks in the acoustical enclosures which has been provided as noise control devices. Proper patching of the enclosures often produces a significant noise reduction in these cases.

b. Commercial Noise Sources

Commercial heating, ventilating, and air conditioning equipment frequently need only maintenance to permit it to comply with noise limits. Municipal building inspectors seldom are concerned with the degree of maintenance of existing buildings and their equipment. Fire department inspections might reveal such deficiencies if this department received the responsibility for enforcement of this kind of noise control law. Shock and vibration mountings and full or partial enclosures for commercial equipment frequently need maintenance. If a noise control and abatement program includes an engineer who is familiar with noise and vibration control engineering techniques for buildings, he may be able to influence property managers to begin preventative maintenance programs that reduce noise before failures create violations of the noise limits.

The ninth and tenth columns in Exhibit IV-1.

c. Industrial Noise Sources

The treatment of these problems by requirements for maintenance is similar to that for commercial noise sources. Construction and agricultural equipment frequently is poorly maintained. A noise control ordinance that requires that construction equipment be operated with its mufflers, dampers, vibration mounts, and sound absorbing equipment intact and functioning will make significant reductions in noise at construction sites. The costs of mufflers for various off-highway and stationary equipment has been collected in a recent report to the U.S. Department of Transportation[1].

d. Transportation Noise Sources

The most common provision for noise control of motor vehicles is the requirement that each vehicle shall be operated with an unmodified muffler in good repair. Enforcement of such a requirement probably is the most effective single factor in reducing the noise level in most communities. This is substantially equivalent to the source-distance countermeasure except that no special training or equipment is needed. Police officers are familiar with the operations of mufflers and exhaust pipes and easily can detect when one is faulty or when it has been modified or replaced to produce higher noise levels.

The owners and operators of cars, trucks, and motorcycles that have exhaust equipment which is defective because it is in poor repair usually will respond to warnings and summonses, and when the drivers in the community become aware that the police are stopping cars with defective equipment, repairs frequently will be made before the vehicle is stopped. It is estimated that enforcement of the muffler provisions of a local ordinance will require the equivalent of one half of a full time police officer in a city of 100,000 people.

There is insufficient data available to give a comprehensive picture of compliance costs. Most communities permit fines of up to $300 for most noise violations, in many the fines for motor vehicles range between $25 and $50. Some apply the "soft fuzz" approach and dismiss the violation if the compliance is proven prior to the court date.

[1] *Toth, W.J., "Noise Abatement Techniques for Construction Equipment", Society of Automotive Engineers, Warrendale, Pennsylvania, August 1979, Appendix C.*

Motor vehicle muffler repairs are often required to meet the noise ordinance. This violation is one that occurs to a broad segment of the citizens of the community, and so expensive repairs could erode the public support for the ordinance. Fortunately most muffler repairs vary between $20 and $100; high performance vehicles generally cost more. Trucks require mufflers costing up to $300, depending on size[1]. In Boulder, Colorado, (a city of 80,000) which dismisses fines for immediate compliance, officials estimate that $26 is spent for every $1 in fines collected. From 1969 to 1976 they average about $1,000 per year in fines, so they estimate about $26,00 per year in vehicle repair costs. In Salt Lake City, in the first five months of enforcement, they estimated annual repair costs to be $11,500 for motor vehicles[1].

It is possible for a community to enforce maintenance provisions through an inspection program. Almost all periodic motor vehicle inspection programs are statewide, but in the vicinity of Portland, Oregon, a combination of exhaust monitoring for air quality and acoustical monitoring for noise control has been introduced. ". . . this program is extremely efficient in labor and material cost. Also, fees are collected to cover the incremental costs associated with the noise tests."[2] The program uses five sound level meters and two inspectors per vehicle for an average of two minutes inspection time per vehicle[3]. No measure of the effectiveness of this level of enforcement is available.

2. Retrofit

a. Domestic Noise Source

An ordinance might require that a specific existing noise source must be quieted by adding a part, e.g. a newly developed muffler might be required for all non-electric power lawnmowers in a community. The costs and effectiveness of such a provision are like those of the maintenance program. One unusual retrofit possibility is the use of muzzles on dogs to keep them from barking. This option is included in the animal control programs discussed in Section IV-B.4.

[1] *Chanaud, R. C. and Simmons, R. A., "Community Noise Ordinance Workbook", EPA (n.d.) (draft) p. 5-6.*

[2] *Letter from Robert Stone, Technology + Economics, Inc., Cambridge, Massachusetts to Dr. Kurt Askin, EPA, 27 August 1979, p. 3.*

[3] *Ibid, Appendix B.*

b. Commercial Noise Sources

Requirements to equip all existing noise sources of a particular type with particular mufflers, shields, or absorbing materials are possible but expensive because not all sources may require them. Retrofitting on a case-by-case basis is less expensive to the owner of the equipment but requires more investigatory time by enforcing officers. No estimates of the cost or effectiveness of retrofitting are available.

c. Industrial Noise Sources

The situation with industrial sources is similar to that for commercial sources.

d. Transportation Noise Sources

Retrofit requirements are seldom imposed on motor vehicles, but they have been imposed on railroad and guided mass transit equipment, especially a requirement for damped wheels, for grinding wheels, and for welding and grinding joints in tracks. Estimates of the cost and effectiveness of community action against rail equipment are not available. Aviation noise sources have been required to add particular quieting equipment by Federal order.

E. CONSTRUCTION CODES*

1. Product Regulations

Product regulation countermeasures include restrictions on the characteristics of products that are used in the community and requirements that the products be labeled concerning their noise emission characteristics. The ability of a community to impose these requirements is limited, as is discussed below.

a. Domestic Noise Sources

Communities have difficulty imposing restraints on the products that are sold and used within their boundaries unless they are regarded as socially undesirable, e.g. fireworks and alcoholic beverages. Building codes can restrict the use of some materials and some construction practices, however. Exhibit IV-10 is reproduced from a recent

The eleventh, twelfth, and thirteenth columns in Exhibit IV-1.

report on an EPA "Quiet House" program.[1] The values in Exhibit IV-10 are predicted; the experiment has not been performed, but they are indicative of the advantages that are available in remodeled housing in the New England area. The program includes comparison of the noise level (a) inside a residence kept as it is now for use as a reference and (b) inside a residence modified and improved in construction and by the installation of appliances and equipment which have been selected for their energy and noise conservation characteristics. If the reference house is modified to put it in conformity with article 22 of the Massachusetts State Building Code (bringing it up to current standards), then the noise reduction benefits through the "envelope" with the windows closed will be only 3dB(A) rather than the 8dB(A) shown in Exhibit IV-___. The costs of the predicted noise reductions have not yet been broken down in a form suitable for a community's use.

It is unlikely that community will require products used in the home to bear any labels other than those required by the EPA. Thus the cost to the community of this countermeasure is only the cost of assuring that the merchants do not remove labels from products. The effectiveness and the cost of such enforcement are negligible.

b. Commercial Noise Sources

EPA is beginning to certify products as Low Noise Emission Products, (LNEP) for which Federal law permits the General Services Administration to pay as much as 25 percent more than for the least expensive noncertified similar product.

Generally, such certified LNEPs have noise emissions that are 5dB or more lower than those required of EPA regulated products. The number of such products and the cost differential are not yet available. The building codes of communities frequently include requirements for construction especially HVAC equipment, that meet certain building standards. Estimates of the effectiveness and the costs of the requirement are not available. The subject is discussed more fully in Section IV-D.2.

c. Industrial Noise Sources

The situation on industrial sources is similar to that for commercial noise sources.

[1] *Keast, D. N. and Berman, D. D., "Energy Conservation and Noise Control in Urban Residences: Demonstration Program Plan", Bolt, Beranek and Newman, Inc. Cambridge, Massachusetts, July 1979, p. 32.*

TABLE 2a. SUMMARY OF ESTIMATED INTERIOR NOISE EXPOSURES IN THE DEMONSTRATION RESIDENCES, WITH THE REFERENCE DWELLING IN ITS PRESENT CONDITION

Type	Reference Dwelling (Present Condition)	Improved Dwelling	Noise Reduction Benefits
Through envelope			
closed windows	L_{dn}=53dB[1]	L_{dn}=45dB	8dB(A)[5]
open windows	L_{dn}=62dB[2]	L_{dn}=52dB	10dB(A)[6]
Interior Sources (@ 3 ft)			
Furnace	-	-	no change
Hot Water Heater	-	-	no change
Range & Oven	-	-	no change
Range Hood[3]	67dB(A)	55dB(A)*	12dB(A)
Dishwasher[4]	70dB(A)	56dB(A)	14dB(A)
Garbage Disposer[3,4]	88dB(A)	68dB(A)	20dB(A)
Refrigerator/Freezer[3,4]	50dB(A)	37dB(A)	13dB(A)
Clothes Washer[3,4]	71dB(A)	51dB(A)	20dB(A)
Clothes Dryer[4]	63dB(A)	53dB(A)	10dB(A)
Window Air Conditioner[3,4]	65dB(A)	53dB(A)	12dB(A)

Sources:
1. Measured
2. Estimated per EPA 550/9-74-004
3. BBN Report 3791
4. Fig. 3 of EPA NTID 300.1.
5. BBN Report 3903
6. See Sec. 3.1.

*To be installed with muffler

Exhibit IV-10. Estimated Interior Noise Exposure for Different Constructions and Equipment

d. Transportation Noise Sources

Communities probably will be able to require product specifications for noise characteristics only of buses and rail transit cars that are used in the community. Cost-effectiveness data are not yet available from EPA's bus mall and a bus retrofit noise programs.

2. . Building Insulation

The considerations in the paragraph that follow are applicable to the reduction of noise from all four kinds of sources.

Transmission Loss

Interior party walls and exterior walls (facades) are primary candidates for increased acoustical insulation to reduce noise transmission between apartments and contiguous houses and from the exterior to the interior, respectively. Noise isolation is measured in terms of "transmission loss", which is a comparison between the sound incident one side of a partition and the sound transmitted through and leaving the other side of the partition. The materials and construction of a wall determine its transmission loss, and the transmission loss is different at different frequencies.

Two distinct cases, interior and exterior walls, are considered separately to provide quick explanation for particular situations.

I. Interior Partitions

In general, the interior partitions that are of interest in noise control are those that separate two dwelling units (party walls), those that contain mechanical services (chase walls), and those that separate one dwelling unit from public space (halls) or mechanical equipment.

Since transmission loss is frequency dependent, a simplified single number rating was devised by the American Society for Testing and Materials. This number is the standard method of rating interior partitions in the United States. The rating is called Sound Transmission Class (STC) and describes the noise isolation properties of a partition.

A complete test method used to rate partitions and definitions of STC can be found in ASTM Standard Test Method for Measurement of Airborne Sound Insulation in Buildings, E336-77 and Classification for Determination of Sound Transmission Class, E413-73.

METHODS TO ENFORCE LAWS

Proper insulation for partition or facade new construction is usually specified by the local or State building code. The compliance is determined by one or two methods.

1. Construction Specifications: The panel or element under consideration is specified such that when constructed, it meets predetermined ratings so the contractor need only show plans which can be compared to a file of acceptable plans. If the submitted plans are acceptable no further investigation need be done. If similar constructions are not in the file, a performance specification may be required (see below). Building inspectors normally can enforce a construction specification for a particular building in about 2 hours.

2. Performance Specification: This method requires an on-the-site field test or a mock-up in a laboratory. This test is usually quite complex and is often performed on systems of components or on unusual designs. The field test provides a means to measure the actual noise isolation of the partition. A mock-up often provides a reasonable approximation to the actual noise isolation. Building inspectors normally can enforce a performance specification for a particular partition in about 4 hours.

The method for rating a new type of partition requires an elaborate field or laboratory test. Fortunately, most construction practices found in this country use standard partitions for which ratings already exist. Thus, the specifications for the partition can indicate a rating, assuming construction is performed with reasonable skill.

A — HOW TO CHOOSE AN STC RATING

The required STC rating will depend on the use of the space on each side of the wall and the amount of isolation that is desired. Partitions with high STCs cost more than partitions with lower STCs, so the STC specifications in the building code affect the cost of construction. Exhibits IV-11 and IV-12 provide guidance in selection of interior partitions.

		Adjacent Room	Luxury	Average	Minimum
Residential, Including Motels, Hospitals, and Dormitories	Bedroom	Bedroom	55	50	45
		Living Room	60	55	50
		Kitchen	60	55	50
		Bathroom	60	55	50
		Corridor	55	50	45
		Lobby	60	55	50
		Mech. Room	60+	60	55
		Room in Same Occupancy	50	45	40
	Living Room	Living Room	55	45	40
		Kitchen	60	50	45
		Bathroom	60	50	45
		Corridor	55	45	45
		Lobby	60	55	50
		Mech. Room	60+	60	50
	Kitchen or Bathroom	Kitchen	50	45	40
		Bathroom	50	45	40
		Corridor	50	40	40
		Lobby	60	50	45
		Mech. Room	60+	55	45

Source: Sound Control Construction, 2nd edition, United States Gypsum Co., Chicago, Ill., 1973, p.58

EXHIBIT IV-11: Recommended Sound Transmission Class (STC) for Different Rooms

B — STC'S OF SEVERAL TYPICAL[1] PARTITIONS

	STC
1/4 plywood nailed to 2 x 4 wood studs on both sides, 16" on center	24
1/2" wood fiberboard nailed to 2 x 4 wood studs on both sides, 16" on center	28
1/2 gypsum board nailed to 2 x 4 wood studs on both sides, joints taped and sealed	33
5/8 gypsumboard screwed to 5/8 metal studs, 24" on center	39

Add absorption in cavity	add 5 points
Staggered stud	add 10 points
Use resilient clips	add 5 points each side

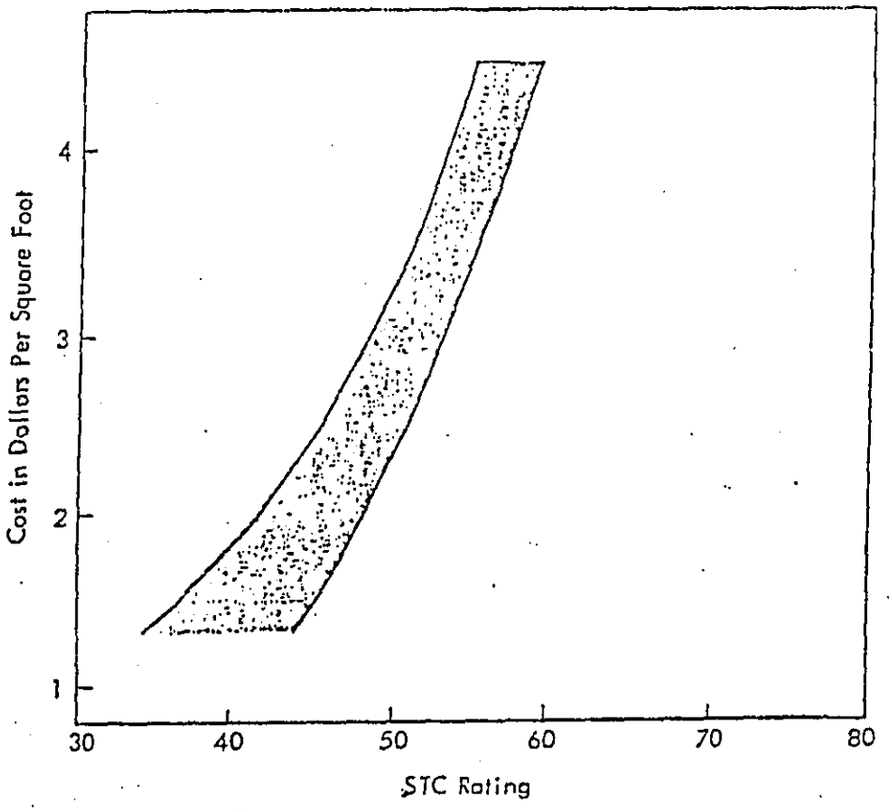
4" masonary block, lightweight	36	Dense	38
12" masonary block, lightweight	51	Dense	53
6" reinforced dense, concrete	46		
8" reinforced dense, concrete	51		
12" reinforced dense, concrete	56		

[1] *A comprehensive list is given in "Catalog of Sound Transmission Class (STC) and Impact Insulation Class (ILC) Ratings for Wall and Floor/Ceiling Assemblies," Office of Noise Control, California Department of Health Services, 2151 Berkeley Way, Berkeley, California, 1980.*

Exhibit IV-12: STCs of Different Typical Partitions

C — COSTS OF PARTITIONS

Exhibit IV-13 shows the approximate cost of partitions exhibiting a certain STC rating. The costs are 1977 dollars and are subject to local variation.



Source: Sharp, B. H. "The Control of Transportation Noise in Residences", Noise-Con 77, Hampton, Virginia, October 18, 1977. (presented, not published in Proceedings)

EXHIBIT IV-13: Cost Per Square Foot for Typical Wall Constructions As A Function of STC Rating

Any openings such as cracks, outlet openings, and ducts that reduce the integrity of the partition, seriously degrades the acoustical insulation of the wall. Hence, these are to be avoided. If the partition contains a door, its STC must be as high as the walls if the full value of the wall's STC is to be realized.

II. Exterior Partitions

Exterior partitions separate interior noisy spaces from the outside. In general, when sound control is considered for facades, it is to insulate against transportation noise. Standard construction techniques found in the continental United States provide on average about 10dB attenuation. However when there are noise leaks in the facade (from air conditioner outlets, from poorly installed windows, or from doors with cracks around the edges), or when ventilation needs require the windows to be mostly open, the noise reduction characteristics of the facades are much lower. Either high noise levels or low transmission losses may require additional acoustical insulation.

There are several methods of rating facades to insulate against exterior noise. The Federal Highway Administration (FHWA TS-77-202) uses a rating scheme called Exterior Wall Noise Rating (EWNR) which is based on a "typical" frequency distribution of vehicular traffic and a known interior noise spectrum. Both a plain facade and a composite facade (made up of windows and/or doors) can be rated by this method.

The National Bureau of Standards (Design Guide for Reducing Transportation Noise in and Around Buildings - BSS 84) uses the concept of Shell Isolation Rating (SIR).* This rating is similar to the STC rating mentioned earlier, but the SIR can be used to describe the noise isolation properties of a partition and/or an entire enclosure. The NBS report contains a large amount of SIR data and methodology to calculate SIR for other constructions.

ASTM is presently (Oct 1979) working on a new method to rate outdoor partitions. This method may be in the public domain by the time this report is released.

Canadians use another rating method called the Acoustical Insulation Factor (AIF) which is similar to the SIR system.*

III. Retrofitting Existing Buildings

The previous sections dealt with evaluation of existing buildings and estimation of cost for new buildings. Another countermeasure is to retrofit an existing building to reduce noise to the interior. This option is particularly attractive because most of the actions taken to reduce noise transmission also reduce heat transmission and save energy. Sometimes the energy saving will pay the full cost of the acoustical countermeasure.

The following guidelines are furnished in order of increasing cost and in order of recommended treatment:

	Estimates as of 1977	
	Approx. Noise Reduction (in dB)	Approx. Cost
Interior Partitions*		
o Plug all leaks	Up to 7	$ 25+
o Improve gasketing on doors	Up to 7	$ 75+
o Furnish source room/receiving room with heavy sound absorbing furniture and wall coverings	+ 2	N/A
o Build up partition	+ 20	$ 250+
Facades**		
o Plug all leaks	Up to 7	$ 100
o Improve gasketing on doors and windows	Up to 7	$ 200
o Furnish interior with heavy sound absorbing furniture and wall coverings	+ 2	N/A
o Replace lowered windows	+ 10	$ 400
o Add storm windows	+ 7	$2,500
o Replace hollow door with solid core door	+ 10	$ 620
o Acoustical windows	+ 10	$4,200
o Build up partition	+ 20	$2,000
o Insulate against aircraft noise	+ 20	$2.50 ft.^{2***}
	+ 30	$3.75 ft.^{2***}
	+ 40	$9.75 ft.^{2***}

* For insulation against noise between adjacent rooms

** For insulation against surface transportation

*** 1973 dollars

\+ per pattern

Source: Sharp, B. H., "The Control of Transportation Noise in Residences" Presentation at Noise-Con 77, Hampton, Virginia, October 18, 1977.

3. Barriers

For the purpose of this section, barriers are defined as noise control measures used to reduce noise levels from vehicular traffic. Barriers for other sources are discussed in another section. (Information on railroad barriers will be supplied by EPA when it is releasable to the public.)

In order to select a barrier a rather sophisticated analysis must be performed because the acoustical isolation of a barrier is a function of

1. The height and length of a barrier,
2. the height of the source and of the receiver,
3. the distance from the barrier to the source and to the receiver,
4. the frequency content of the sound of the source, and
5. to a lesser extent, the shape and material of the barrier.

The references in Section VI explain the design process for barriers. When barriers are considered, an important factor is their acceptability to the community.

Barriers can reduce noise complaints by two means: 1) to reduce the received noise, and 2) to reduce the apparent noise by visually blocking the source from the receiver. Nevertheless, many people feel barriers are not appropriate to the aesthetic or safety concerns of the community. The acceptability of barriers is extremely site specific and depends greatly on the style of barrier (discussed later), the view being blocked by the barrier, and the noise reduction afforded.

The more the barrier can be camouflaged by blending-in with the natural landscape, the better the chance of its acceptance. Snow[1] provides summaries of existing experience concerning community acceptability.

[1] *Snow, C. H., "Highway Noise Barrier Selection, Design and Construction Experiences," U.S. Department of Transportation Implementation Package 76-8.*

Costs

Roadway noise barriers are always expensive and alternate noise control measures should be considered, if possible, simultaneously with barriers. The costs of barriers (assuming the right-of-way is owned) depend on type of barrier, material used, and height.

The cost factors for the three most common types of barriers are as follows (costs are rough national averages in 1976-1978 dollars):

Earthen Banks "Berms"

Typically $1.00-2.00/cubic yard up to $6.00/cubic yard
With landscaping $30.00 per linear foot

Timber Walls

Typically $3.00-5.00/square foot
About $50.00 per linear foot

Masonary Block and Concrete

Typically $3.50-9.00/square foot
About $90.00 per linear foot

Reference 1 contains data that yields the following rough averages.

Type	Average Height	Average Approximate Attenuation	Average $/ft.	Average $/ft./dB reduction	
Earthberm	9'	6.7 dB	14	5.7	
Timber	9.8'	7.3 dB	44	6.2	
Metal	9.3'	10 dB	82	9.0	(based on few data)
Stucco	6'	9 dB	49	7.6	(based on few data)
Concrete/ Masonary	8.5'	9.9 dB	58.6	8.71	

Combinations of barriers (berms and timber or metal) can be used and are discussed at length by Snow[1].

[1] *Ibid.*

A recent report* describes the costs and the noise reductions of barriers installed along side of railroad car retarders in a classification yard. The noise source was the retarder action on the wheels of the car and therefore was at rail height. The barriers were constructed from commercially available absorbent panels. Part of the time the panels were covered or reversed to make them reflective rather than absorbtive. The barriers were 143 feet long and 8-12 feet high. At a distance of 100 feet from the tracks and directly opposite the retarders, eight-foot absorptive barriers gave more than 20dB of insertion loss, and twelve-foot absorptive barriers gave more than 25dB of insertion loss. Reflective barriers produced only about half those amounts. The insertion loss for absorptive barriers increased by between 1.5 and 3dB per foot of height between eight and twelve feet; the increase was smaller for reflective barriers.

The cost of the barriers was about $160 per linear foot for the eight-foot barriers and about $230 per linear foot for the twelve-foot barriers. This amounts to between $19-20 per square foot. Material costs were between 70-75 percent of total costs.

These data may be compared with those from a 1975 report given in the Strategy Guidelines document. The tables reproduced below and on the next page are from pages 3-70 and 3-73.

Table 3-13

Cost of Barriers (from Reference 6)

Barrier Height in Meters (feet)	Application	Cost per Linear Meter (feet) 1977 Dollars
3.0 (10)	Highway	$186 ($ 57)
4.6 (15)	Highway/ Railroad	$281 ($ 85)
6.1 (20)	Railroad	$425 ($130)

*Morgan, James A. and Uno Ingard, "Railroad Retarder Noise Reduction: Study of Acoustical Barrier Configurations", Burlington Northern, Inc., St. Paul, Minnesota, May 1979.

Table 3-14

(a) Barrier Effectiveness Ratios* for Low and High Barriers, by Noise Source[a]

Barrier Height in Meters (feet)	Autos and Motorcycles	Trucks and Buses		Rail[b]		Aircraft[c]
		Low Speed	High Speed	Locomotive	Cars	
2-4 (6.1-12.2)	1.0	0.7	0.9	0.3	0.8	0.0
4-6 (12.2-18.3)	1.0	0.9	1.0	0.4	1.0	0.0

(a) For nonvehicular noise sources (i.e., power plants, factories), estimate the ratio based on relative source height to the standard source - automobiles. Values based on noise reductions given in Reference 6.

(b) If the source noise levels are not separated for locomotives and cars, use an average of the two ratios.

(c) Zero effectiveness for aircraft in flight. For some areas along the sideline of airport runways or near aircraft engine test areas, where the dominant noise source is located on the ground, barriers can be effective - effectiveness ratios of 0.3 and 0.6 are estimated for 2-4 and 4-6 meter barrier heights respectively.

(b) Average Reduction of Automobile Noise by Low and High Barriers[6]

Barrier Height in Meters (feet)	Auto Noise Reduction in Cell Near Barrier (in dB)
2 (6.1)	10
3 (9.1)	13
4 (12.2)	14
5 or more (15.2 or more)	15

*"Barrier effectiveness ratios describe the effectiveness of barriers in attenuating noise from different sources relative to an established "norm". Each ratio is the noise reduction (in dB) of a source divided by the noise reduction of the "norm". Because they are the most prevalent noise source in the community, automobiles have been chosen as the "norm" source and, effectiveness ratios for other sources have been developed based on the effectiveness of barriers on automobiles". (Strategy Guidelines document, p 3-72).

F. OTHER ABATEMENT METHODS

1. Planning and Zoning

In the long run this countermeasure is the most effective and perhaps is the most cost-effective of all the countermeasures. It consists of separating geographically the noise sources from the sensitive receivers and thus lengthens the acoustic path between the two. Unfortunately, it takes a long time to become operative. Keeping residences away form the railroad or the highway and from under the flight paths of aircraft may be politically difficult and expensive in terms of forgone tax revenues.

Communities that have long established zoning ordinances and planning departments are much better able to accept new noise sources than those for which few precedents exist. Newer unplanned and uncontrolled communities and older communities with many prezoning, nonconforming land uses are particularly susceptible to intrusive noise sources. In some cases these sources are of great benefit to the community as employers or as transporters of goods and people to their economic uses. An early inclusion of noise as one of the criteria for decision in approving development plans and zoning variances is a step toward community noise control. Effectiveness and cost data for this countermeasure do not exist in a form useful to a planner of a community noise program.

2. Compensation

One method of reducing complaints and unfavorable attitudes about noise is to pay the people who are exposed to high noise levels for their trouble in being so exposed. The Strategy Guidelines document gives some figures for the decrease in real property values as a function of noise level. Table 3-17 (p. 3-79) from that document is reproduced below.

Annualized Property Value Reduction (V_R) in 1977 Dollars
Due to Selected Increases in Noise Level[10, 22-24]

	Increase in Noise Level (dB)				
Source	5	10	15	20	25
Aircraft Noise	$220	$440	$660	$880	$1,100
Highway Noise	$ 55	$110	$165	$220	$ 275

[illegible] estimates that a reduction between 4 percent and 20 percent of the [illegible] property value may apply to property over which there are frequent aircraft [illegible]. (p. 3-11)

[illegible] ates of the reduction in value of residential real property value are summarized [illegible] following table:

Source	Dollar Reduction Factors	Notes
[illegible][1]	$60 to $646 per dB(A)	Noise Pollution Levels between 60 and 80 average house evaluation = $31,000
[illegible][2]	approx. $58 per dB(A)	Index is $(I_{10} - L_{90})$ where L_{10} ranges from 360 dB(A) to 60 dB(A)
[illegible][3]	$24 to $190 per dB(A)	Uses Gamble et al data average $75 per dB(A)
[illegible] Faucett[4] Associates	0.3% per dB(A) at L_{10}	Range of noise levels not given

[illegible][2] estimated that jet aircraft noise pollution damage is about $130 per residential property per unit increase in the Noise Exposure Forecast in metropolitan areas. New [illegible] City applied these values to the existing noise situation and found an average [illegible]ation of $600 per one-family residence and $480 per multiple-family residence [illegible] by motor vehicle traffic and $650 per residential unit for airport noise impact.

[illegible]ther measure of noise impact cost is the average sound through litigation in noise [illegible]ct. In airport litigation[5] an average of $26,700 per plaintiff was sought. Since [illegible]tion arises out of severe noise impact and damages sought generally far exceed [illegible] given, it may be that these values are not incompatible with those given above."[6]

[illegible]. H. B. et al, *"Community Effects of Highways Related by Property, Values,"* [illegible] Park, Pennsylvania, *August 1973.*

[illegible], J. P., *"The Effects of Mobile-Source Air and Noise Pollution on Residential [illegible]erty Values", U.S. Department of Transportation document DOT-TSC-75-76, April* [illegible]

[illegible], R. J. and D. E. Wise, *"The Effects of Highway Noise and Accessibility on [illegible]ential Property Values", MATHTECH, Inc., Princeton, N.J., March 1977.*

[illegible] *Techniques for Highway Noise Valuation and Compensation", Jack Faucett* [illegible], Inc., *Chevy Chase, Maryland, July 1975.*

[illegible] et al, *"The Development and Formulation of Ambient Noise Quality Zones* [illegible] *Standards for the City of New York", a report to the City Council by the* [illegible]*mental Protection Agency, July 1975.*

[illegible] *Noise Ordinance Workbook", EPA n.d. (draft) n.d. p. 5-8.*

If these numbers are indicative of the decrease in the value of property as a result of noise pollution, the community is already compensating the owners of the property by valuing the land and improvements at a lower assessment and thus collecting lower taxes than it otherwise would. This countermeasure does not abate or control noise and its effectiveness has not been measured in terms of changes in attitude towards noise or in the number of complaints received. The economic effectiveness can be measured in terms of forgone income by the community in exchange for willingness of the population to live in the noise environment.

3. Education and Public Awareness

Almost all communities that have effective noise control programs include projects for education about noise and its effects in the schools, about animal and motor vehicle noise to possible offenders, and about the program itself to complainants and offenders. They also try to make the public aware of the existence of the program and its accomplishments through press, radio, television, and other channels for public information.

If the citizens learn about the causes and effects of noise and simple methods for noise control, neighborhood noise can be reduced substantially. Making children conscious of noise in elementary or high schools will help them be aware of the noise they produce. Adult education classes, speakers from the EPA or from the Acoustical Society of America (always willing to talk about the subject) are ways in which adults can learn about noise. A noise team made up of enforcement officers can discuss the solutions to noise problems with source owners or operators, often with excellent results.

Although all specialists in community noise control and abatement agree on the value of an education program and public awareness, no one has data concerning the effectiveness for a given expenditure. EPA is conducting some studies of public education on noise, but no effectiveness data are yet available. One of the characteristics of this countermeasure is its interaction with other countermeasures. For example, a good public awareness program may prevent complaints that would have to be answered by an animal control progrm or a police officer enforcing a curfew. In addition the education programs contribute to reduction of noise from all sources, so the educational money cannot be allocated among them.

5. Tax incentives

Tax incentives may be given to owners of noise sources to assist or to encourage them to reduce the noise from their sources. A negative tax incentive is a penalty for operating the noise source. Fines for violation of the noise ordinance constitute one form of a penalty, but the tax penalty may apply to longer term violations or to operation in the absence of an ordinance. The Strategy Guidelines document discusses three forms of these tax measures (pp. 3-87 to 3-95). No data concerning cost or effectiveness are available.

6. Population Relocation

In cases of extremely high levels of noise exposure, the only way to protect the citizens may be to relocate their residences and workplaces. Such examples have occured in the case of houses directly on the edge of express highways or at the end of airport runways. There is no reduction in the noise levels in the community, but there is a reduction in the number of people who are exposed to it. The cost of the countermeasure is the cost of acquiring and usually destroying the residential or commercial property and the resulting loss of tax income. No estimates of the costs or the reduction of LWP can be given, for the situation is so specific to a community that no generally applicable numbers are available. Provision for such countermeasures may not be required in the noise program budget, because the number of such cases is quite small.

V. SUGGESTIONS FOR THE USE OF THIS MANUAL

1. Choosing the Structure of a Community Noise Program

The economic, demographic, and geograhic nature of the community that uses this Manual will determine, to a large extent, the structure of its noise abatement and control program. Communities that have most of their population employed in the community differ from those that are primarily residential suburbs with few local industries. Some communities have two or three different populations: permanent, voting taxpayers and transients who may be college students, vacationers, or military personnel from nearby training bases. Some communities have good control over their own noise environments, while others are dependent upon the activities and inclinations of larger or noisier adjacent communities or Federal installations. Some States have an active, effective noise control program to which the local program should be complementary; other States have no program at all and local authorities will be entirely on their own.

Legal restrictions also influence the structure of the local noise program. In some States local governments may write noise limits only if they are no less restrictive than those of the State; in other States the noise limit may be adopted only if they are no more restrictive. Some States have building codes that preempt anything the local government could adopt.

Other environmental programs adopted by the community will have included considerations of this sort, so its legislative and executive officers will be prepared for such influences on the noise program. The influences will apply primarily to the classes of noise sources that are addressed and to the techniques of enforcement. The two topics interact, but there is a significant difference in the ways an ordinance aimed at any particular source of noise can be enforced. In some communities only nuisance laws are used and no acoustical measurements are needed. Other communities use measurements, but persuasion rather than citations and fines are used to achieve the abatement. Some communities give the enforcement responsibilities entirely to the police department and instruct them to enforce with citations and appearances in court to support cases that will result in fines. Other communities designate responsibility to the health or the environmental departments with assistance by the police for the dangerous cases of stopping moving motor vehicles or investigation of family fights.

2. Use the Experience of Other Communities

A recent survey[1] found that the following kind of regulations were the major kind of quantitative, acoustic means for community noise control:

motor vehicle codes
recreational vehicle restrictions
construction site restrictions
building site restrictions
building codes
zoning and land use codes

Each of these types of ordinance or regulation was discussed in the Section IV (several other kinds of regulations for qualitative or nonacoustic means of controlling community noise also were discussed).

Exhibit V-1 is reproduced from this report.[2] It shows the number of communities that have quantitative standards for particular types of sources and the number that perceive these sources are significant problems. Note that, because aircraft and railroad operations are difficult for a community to control, there is a large disparity between perception of the problem and attempts legislatively to remedy it.

[1] *"State and Local Noise Control Activities 1977-1978", U.S. Environmental Protection Agency, Office of Noise Abatement and Control (Draft), May 1979.*

[2] *Ibid, p. 3-12.*

EXHIBIT V-1: Noise Legislation in Communities Compared To Their Perception of Noise Problems

Source of Noise	Number of Quantitative Standards in Legislation	Number of Communities Perceiving Noise Sources as Significant Problem
Industrial Activities	166	147
Motorcycles	165	369
Automobiles	164	315
Trucks	158	353
Entertainment	149	145
Buses	142	188
Construction Equipment	129	151
Home Power Equipment	109	69
Animals	102	170
Recreational Vehicles	91	79
Public Service Vehicles	68	63
Garbage Compacting Trucks	66	124
Railroad Operations	49	226
Aircraft	40	188

See Tables 2-3 and 3-4 for survey questions.

Exhibit V-2 is also reproduced from this report.[1] It shows the number and percentage of the communities that enforce their noise control laws for each source.

EXHIBIT V-2: Number of Communities Enforcing Noise Control Laws for Each Noise Source

Source of Noise	Number of Communities	Percent of Communities Responding*
Industrial Activities	77	14.7%
Public and Private Entertainment	59	11.2%
Animals	57	10.9%
Motorcycles	55	10.5%
Automobiles	48	9.2%
Trucks	46	8.8%
Construction Equipment	44	8.4%
Home Power Equipment	36	6.9%
Garbage Compactors	27	5.2%
Railroad Operations	19	3.6%
Buses	16	3.1%
Recreational Vehicles	16	3.1%
Public Service Vehicles	15	2.9%
Aircraft	9	1.7%

[1] Ibid. p. 3-17.

* Based on 524 community responses.

Question 5C. "Please list the number of enforcement actions for each of the following noise sources." (See text)

Exhibit V-3 is also reproduced from this report.[1] It shows the type of local legislation and the enforcing agency for noise control laws in communities.

EXHIBIT V-3: Types of Legislation and Enforcement Agencies for Communities

Legislation	Enforcement Agencies										
	Police/ Safety	Public Health	Environmental Pollution Control	Planning/ Development	Public Works	Building/ Zoning	Transportation	Natural Resources	Other	Total	Percent
Municipal Code	250	39	28	19	18	30	1	1	7	393	52.1
Zoning Code	9	5	3	26	2	80	0	0	1	126	16.7
Vehicle Code	62	1	5	0	1	0	1	0	2	72	9.5
Building Code	3	1	0	0	4	36	0	0	0	44	5.8
Health/Safety Code	8	16	4	1	1	1	0	0	1	32	4.2
Aircraft/Airport Code	0	0	1	0	0	2	1	0	4	8	1.1
Administrative Code	1	0	4	0	1	2	1	0	0	9	1.2
State Statute	27	3	16	2	0	4	4	0	4	60	7.9
Other	7	1	0	1	0	1	0	0	1	11	1.5
Total	367	66	61	49	27	156	8	1	20	755	
Percent	48.6	8.74	8.08	6.49	3.58	20.6	1.06	0.13	2.65		

Question #8. "Please indicate each type of legislation and respective type of enforcement agency."

This report contains valuable information concerning the various organizations and levels of personnel that enforce noise control laws, but there is no consensus that will guide a community that wishes to start a new program. Budgets range from one cent per capita to more than a dollar. Almost all cities that initiate a program do so with an annual budget of between $10,000 and $100,000. Nearly 300 communities indicated that they had noise control laws but did not have a noise control budget. Lack of identification of noise as a line item in the municipal budget makes cost effectiveness data difficult to obtain.[2]

[1] Ibid. p. 3-19

[2] Ibid. p. 4-27

...o communities that responded to questionnaire, 76 percent said they have laws that ...ain noise control provisions, but only 28 percent said that they have noise control ...grams.[1] Exhibit V-4 shows the distribution of noise control activities in the ...ponding communities.[2]

EXHIBIT V-4: Community Noise Control Activities Percent of Program Effort

Activity	Percentage
Complaint Handling	27.8%
Enforcement	17.8%
Development of Noise Laws	13.7%
Environmental Impact	12.5%
Surveys	8.7%
Public Education	7.8%
General Administration	7.2%
Research	4.7%

Question 7C. "Please rank each of the following activities on the basis of the effort devoted to each by the noise control program."

Exhibit V-5 shows the major problems facing community noise control programs.[3]

EXHIBIT V-5: Community Rankings of Major Problems Percentage of Communities Considering Problem Significant

Major Problems	Percentage
Inadequate Budget	16.5%
Lack of Manpower	15.7%
Untrained Personnel	13.6%
Lack of Effective Legislation	12.7%
Enforcement Problems	10.9%
Lack of Political Support	10.8%
Lack of Citizen Support	9.5%
Inability to Demonstrate Success	5.3%
Inability to Meet Objectives	4.8%

Question 11A. "Please indicate the major programs *(sic)* facing your noise control efforts."

---

[1] Ibid. p. 5-4.

[2] Ibid. p. 5-6.

[3] Ibid. p. 5-8

Exhibit V-6 shows the relative success that the reporting communities had in reducing noise from different sources.[2]

EXHIBIT V-6: Significant Progress in Reducing Noise Levels of Various Noise Sources Made By Community Noise Control Programs

Noise Source	Number of Communities	Percent of 542 Community Responses
Public and Private Entertainment	104	19%
Industrial Activities	98	18%
Animals	69	13%
Construction Equipment	61	11%
Motorcycles	53	10%
Home Power Equipment	46	8%
Automobiles	44	8%
Garbage Compactors	42	8%
Trucks	39	7%
Recreational Vehicles	25	5%
Buses	25	5%
Public Service Vehicles	25	5%
Aircraft	21	4%
Railroad Operations	17	3%

Question 11B. "How much progress has been made by your program in reducing the noise levels or noise intrusiveness from the following noise sources?"

[1] *Ibid. p. 5-8.*

both the State and community level, the greatest progress was made in controlling strial and entertainment noise. Control of public and private entertainment noise is rly easy, since non-quantitive, nuisance-type laws can be used by the local police. see, this ranking as number one for communities may simply indicate that many mmunities are doing what is easy to do[1].

same report obtained information concerning the effectiveness of the noise control grams in the communities that reported. Exhibit V-7 shows the effectiveness of the mmunities program as indicative by their response to the question of whether their gram had achieved significant reductions.[2]

EXHIBIT V-7: Ranking of the Most Often Identified Community Noise Problems, The Responses to These Problems, and the Effectiveness of the Responses

ing	Noise Source	Number Having Problem (Percent of 542 Total Responses)	Number With Quantifiable Legislation & Specific Noise Provisions (Percent of Those Having Problem)	Number With Enforcement Actions (Percent of Those Having Problem)	Number With Significant Reduction (Percent of Those Having Problem)
	Motorcycles	369 (68%)	165 (45%)	55 (15%)	53 (14%)
	Trucks	353 (65%)	160 (45%)	46 (13%)	39 (11%)
	Automobiles	315 (58%)	164 (52%)	48 (15%)	44 (14%)
	Railroad Operations	226 (42%)	49 (22%)	19 (8%)	17 (8%)
	Buses	188 (35%)	142 (76%)	16 (9%)	25 (13%)
	Aircraft	188 (35%)	48 (23%)	9 (5%)	21 (11%)
	Animals	170 (31%)	102 (60%)	57 (34%)	69 (41%)
	Construction Equipment	151 (28%)	129 (85%)	44 (29%)	61 (40%)
	Public and Private Entertainment	147 (27%)	149 (101%)	59 (40%)	104 (71%)
	Industrial Activities	145 (27%)	166 (114%)	77 (53%)	98 (68%)
	Garbage Compactors	124 (23%)	66 (53%)	27 (22%)	42 (34%)
	Recreational Vehicles	79 (15%)	91 (115%)	16 (20%)	25 (32%)
	Home Power Equipment	69 (13%)	109 (158%)	36 (52%)	46 (67%)
	Public Service Vehicles	63 (12%)	68 (108%)	15 (24%)	26 (40%)

1. p. 5-8.

1. p. 5-13.

These data are useful as indicators of the difficulties the community is likely to have with a new noise abatement and control program, but the data relate only to programs that contain numerical limits on noise levels. Nuisance laws, curfews, animal control programs, and many other kinds of programs are not included directly. The references in Section VI and the personnel at the EPA regional offices should be consulted, too.

3. Identify the Major Noise Sources

Use the results of the attitudinal and acoustical surveys, the analysis of the complaints, and the record of citizens' opinions, as they are available, to identify the major sources of noise in the community, their relative severity and their locations. Prepare a description of the noise situation using the guidelines developed for the EPA.[1] Carefully note the situations in which there are two or more noise sources that produced approximately equally loud levels in some locations. (In these locations one may not achieve the full benefit from a countermeasure which is directed at only one of the sources.) Examine with particular care the acoustical environment near real property improvements that may become candidates for quiet zones, and list all the sources that will cause the noise level to be above the chosen or recommended levels for such zones.

4. Make a Preliminary Choice of Countermeasures

Use the table in Section IV, Exhibit IV-1, to choose the countermeasures that offer the highest effectiveness in the shortest time for each of the major types of noise source that have been identified in the previous step. Although long-term countermeasures are frequently the most effective, make the choice in favor of the immediate or near-term ones initially. If results are not demonstrable fairly quickly, there may be no funding available for later projects.

[1] *"Format for the Presentation of Community Noise Data Derived from LISTEN Surveys," Wyle Laboratories, El Segundo, California, February 1980.*

Estimate the Cost and Effectiveness of the Preliminary Choice of Countermeasures

Using the data furnished in Section IV, estimate, whenever possible, the effectiveness of the countermeasures in the preliminary choice. Most of the cost of enforcing and planning the noise on program will be personnel costs, so use the factors developed in Section IV-B, and scale the personnel requirements from the 100,000 person reference level used in this Manual. Estimate the cost of sound level meters at $800 each. Estimate the cost and the effectiveness of each countermeasure as an abatement project.

Estimate the Interactions Among the Countermeasures

Usually the cost of noise countermeasures decreases and the effectiveness increases when several are adopted at the same time. They are mutually reinforcing and there are economies of scale. For example, motor vehicle noise programs are enhanced by transportational programs; barrier construction in one part of a community makes for lower costs for barriers in another part; establishment of a permit program makes enforcement of noise curfews and location restrictions much easier. Estimate these interactions and modify the costs and effectiveness as appropriate. No numerical guides can be given, but experienced budget officers will be able to estimate the modifications, especially with help from the EPA.

Prepare Plans

Prepare a tentative annual budget for the noise program and compare the requirements of the preliminary choice of countermeasures with the budgetary limitations. If some of the countermeasures seem too expensive, try less effective, but less expensive, ones for the same target. Adjust the countermeasures to see whether the sensitive areas of the particularly troublesome sources are treated adequately. Examine the plan to see whether the quiet zones can be created for suitable land uses and whether there are areas in which there are several about-equally-troublesome noise sources are really going to benefit from the countermeasures that are proposed.

A suggested minimum community noise program consists of the following:

(a) a nuisance law(s)
(b) time, location, and duration limitations on specific activities
(c) inclusion of noise considerations in the planning and zoning decisions
(d) an education and public awareness program
(e) establishment of a noise complaint or noise information center.

Some of these countermeasures cost little and can be supported partially by other programs. A little more funding is required to include operational controls, maintenance, and retrofit programs, and significant funds will be required to support motor vehicle source-distance laws, property line standards for stationary sources, and barrier construction.

Re-examine the preliminary choice of countermeasures and determine whether substitutions, deletions, or additions profitably can be made. Prepare the full plan and present it to the legislative and executive leaders of the community using the techniques described by the EPA.[1]

[1] Ibid.

SECTION VI

BIBLIOGRAPHY

Acoustical Society of America, Report on the Conference on Acoustics and Societal Problems Held at Arden House. Harriman, New York, June 18-21, 1970.

Adams, B., "The Feasibility, Practicability and Cost of the Soundproofing of Schools, Hospitals, and Public Health Facilities Located Near Airports." Report to Congress, Department of Transportation, FAA, July 1977.

American Association of State Highway and Transportation Officials, Guide on Evaluation and Attenuation of Traffic Noise. Washington, D.C., published 1974.

American Society for Testing and Materials, 1978 Annual Book of ASTM Standards, Part 18. Philadelphia, Pennsylvania.

Anderson, Robert J., Wise, Donald E., The Effects of Highway Noise and Accessibility on Residential Property Values. MATHTECH, Inc., Princeton, NJ., March 1977.

Anon., Guide to the Soundproofing of Existing Homes Against Exterior Noise. Wyle Laboratories Report WCR 70-2, March 1970.

Anon., Proceedings of Conference on Highway Traffic Noise Mitigation. FHWA, Los Angeles, California, December 11-15, 1978.

Sound Control Construction: Principles and Performance. 2nd Edition. U.S. Gypsum, Chicago, Illinois, 1973.

Berendt, Raymond D. and Corliss, Edith L. R., Quieting: A Practical Guide to Noise Control. NBS Handbook 119, U.S. Department of Commerce, National Bureau of Standards, U.S. Government Printing Office, Washington, D.C., July 1976.

Bragdon, C. R., The Status of Noise Control in the U.S.: State and Local Governments. April 1978.

Burlington Northern, Inc., Railroad Retarder Noise Reduction: Study of Acoustical Barrier Configurations. May 1979.

California Dept. of Health Services, Office of Noise Control, Vehicle Noise Enforcement. Berkeley, 1979.

Citizens Against Noise, ABC's of Our Noise Codes. Honolulu, Hawaii, no date.

Citizens Against Noise, Body, Mind and Noise. Honolulu, Hawaii, April 1977.

Citizens Against Noise, Economic and Social Costs of Noise. Honolulu, no date.

Citizens Against Noise, Noise Meter. Honolulu, Hawaii, no date.

Citizens Against Noise, Noise Notes. Vol. 8, No. 8, November 2, 1978.

Citizens Against Noise, Membership Registration Form.

Citizens Against Noise, 23 Hidden Noises . . . in Houses, Apartments and Condominiums. Honolulu, Hawaii, July 1977.

James & Moore, Code of Recommended Practices for Enforcement of Noise Ordinances. Cranford, New Jersey, November 1977.

Davy, B. A., et.al., Insulation of Buildings Against Highway Noise. FHWA Report TS-77-202.

DuPree, R.C., "Evaluation of Outdoor to Indoor Noise Reduction of Building Facades and Outdoor Noise Barriers." State of California, Department of Health, Office of Noise Control Report, July 1975.

Findley, Roger W., and Plager, Sheldon J., "State Regulation of Nontransportation Noise: Law and Technology". Southern California Law Review, Vol. 48:209, 1974.

Gamble, Hayes B., et al., Community Effects of Highways Reflected By Property Values. Pennsylvania State University, Institute for Research and Land and Water Resources, August 1973.

Gately, William S. and Frye, Edwin E., Regulation of Noise in Urban Areas. Manual prepared by the University of Missouri-Rolla for workshops in St. Louis (8/23/71), Kansas City (9/1/71), and Springfield (9/15/71), August 1971.

Hagan, William F., Staff Resources for Noise Control. Verve Research Corporation, Washington, D.C., March 1978.

Jack Faucett Associates, Policy and Techniques for Highway Noise Valuation and Compensation. Final report prepared for National Cooperative Highway Research Program, Transportation Research Board. Chevy Chase, Maryland, July 1975.

Jack Faucett Associates, Development of Noise Enforcement Guidance Materials, Vol. II Recommended Noise Control Regulations and Enforcement Procedures for Use by Police Officers. Chevy Chase, Maryland, September 1979.

Jack Faucett Associates, Guidelines and Sample Training Workbook for Police Enforcement of Noise Regulations. Chevy Chase, Maryland, April 1979.

Jensen, Paul, Jokel, Charles, and Miller, Laymon, Industrial Noise Control Manual. Revised Edition, for U.S. Department of Health, Education, & Welfare, National Institute for Occupational Safety and Health, Bolt, Baranek, and Newman Inc., Cambridge, Massachusetts, December 1978.

Kurzweil, L. G. and Cobb, W. N., Urban Rail Noise Abatement Program: A Description. for U.S. Dept. of Transportation, Transportation Systems Center, Cambridge, Massachusetts, March 1979.

Lewin, Stuart F., Law and the Municipal Ecology, Part Two: Noise Pollution, National Institute of Municipal Law Officers, for the EPA, Office of Noise Abatement and Control, 1970.

...s, Jill Williams, "Noise: A Challenge to Cities", Nation's Cities, National League of Cities, Vol. 6, No. 5, May 1978.

...ann, Alan, Quiet Communities: Minimizing the Effects of Noise Through Land Use Controls. National Association of Counties Research, Inc., March 1979.

...ange, G. E., et.al., Background Report on Outdoor-Indoor Noise Reduction Calculation Procedures Employing the Exterior Wall Noise Rating (EWNR) Method. FHWA Report TS-77-229, March 1978.

...sback, Ernie, Policy and Techniques for Highway Noise Valuation and Compensation. Report prepared for National Cooperative Highway Research Program of the National Research Council. Jack Faucett Associates, Chevy Chase, Maryland, July 1975.

The National Institute of Municipal Law Officers, Model Community Noise and Control Ordance, EPA-550/9-76-003. U.S. Government Printing Office, Washington, D.C., September 1975.

Ontario Ministry of Transportation and Communications, Noise Barrier Evaluation and Alternatives for Highway Noise Control. M.T.C. report number RR180, September 1972.

Pallett, David S., et al., Design Guide For Reducing Transportation Noise in and Around Buildings. U.S. Department of Commerce, National Bureau of Standards, Washington, D.C., April 1978.

Pearsons, K. S., et al, Speech Levels in Various Noise Environments. EPA 600/1-77-025, May 1977.

Plotkin, K. J. and Kohli, V. K., Potential Effectiveness of Barriers Toward Reducing Highway Noise Exposure on a National Scale. Wyle Laboratories, for EPA/ONAC, July 1978.

Quindry, Thomas L., Ed., Standards on Noise Measurements, Rating Scheme, and Definitions: A Compilation. NBS Special Publication 386, U.S. Department of Commerce, U.S. Government Printing Office, Washington, D.C., 1976 edition.

Quirt, J. D., "Keeping Traffic Noise Outdoors." National Research Council, (Canada) Division of Building Research Paper c.1978.

Rackl, Robert, Sutherland, Louis, & Swing, Jack, Community Noise Countermeasures Cost-Effectiveness Analysis. Wyle Laboratories, July 1975.

Roper, William E. of EPA, paper presented before 1978 Society of Automotive Engineers Congress and Exposition, EPA's Rulemaking Program and Strategies for Reducing Surface Transportation Noise. 1978.

Sharp, B. H., "The Control of Transportation Noise in Residences." Presentation at Noise-Con 77, Hampton, Virginia, October 18, 1977.

Snow, C. H., Highway Noise Barrier Selection, Design and Construction Experiences. U.S. Department Of Transportation, Implementation Package 76-8.

Swing, J., "Summary of Noise Reduction Achievable by Dwelling Sound Insulation and Acoustics Barriers." Draft Report ONC-9, State of California, Department of Health, Office of Noise Control, July 1975.

United Nations' Economic and Social Council, Senior Advisers to Economic Commission for Europe Governments on Environmental Problems, Final Report of the ECE Task Force and Noise: National Approaches to Community Noise Problems. April 1978.

U.S. Department of Commerce, National Bureau of Standards, "Standards on Noise Measurements, Rating Schemes, and Definitions: A Compilation". NBS Publication 386, 1973 Edition.

U.S. Department of Commerce, National Technical Information Service, Highway Traffic Noise. A Bibliography With Abstracts. Springfield, Virginia, July 1979. Search period covered, 1964 - June 1979.

U.S. Department of Labor, Noise the Environmental Problem (A Guide to OSHA Standards). Occupational Safety and Health Administration, OSHA2067, Safety Standards, July-August 1972.

U.S. Department of Transportation, Transportation Systems Center, Transportation Noise Bibliography. Cambridge, Massachusetts, no date given, but covers period up to 1974.

U.S. EPA, Office of Noise Abatement and Control, About Sound. U.S. Government Printing Office, Washington, D.C., May 1976.

U.S. EPA, Background Document for Medium and Heavy Truck Noise Emission Regulations. EPA-550/9-76-008, U.S. Government Printing Office, Washington, D.C., March 1976. (Loan)

U.S. EPA, Effects of Noise on Wildlife and Other Animals. NTID300.5, document prepared for the Office of Noise Abatement and Control by Memphis State University, U.S. Government Printing Office, Washington, D.C., December 31, 1971.

U.S. EPA, Noise: A Health Problem. August 1978.

U.S. EPA, Noise and Recreational Vehicles. U.S. Government Printing Office, Washington, Dk.C., December 1976.

U.S. EPA, Noise at Work. U.S. Government Printing Office, Washington, D.C., February 1977.

U.S. EPA, Noise on Wheels. February 1977.

U.S. EPA, Protective Noise Levels: Condensed Version of EPA Levels Document. November 1978

U.S. EPA, Quieting in the Home. Reprinted from National Bureau of Standards Handbook 119 called "Quieting: A Practical Guide to Noise Control" by Raymond D. Berendt, Edith Corliss, and Morris Ojalvo, October 1978.

U.S. EPA, Office of Noise Abatement and Control, Selected References on Noise.

U.S. EPA, U.S. Department of Housing and Urban Development: Noise Abatement and Control Policy, Vol. II, Federal Noise Program Report Series. U.S. Government Printing Office, Washington, D.C., April 1977.

U.S. EPA, Office of Noise Abatement and Control, Boise Community Noise Survey. May 1979.

U.S. EPA, Office of Noise Abatement and Control, Control of Snowmobile Noise. Volume I. Technology and Cost Information. EPA 550/9-74-003-A, U.S. Government Printing Office, Washington, D.C., June 1974.

U.S. EPA, Office of Noise Abatement and Control, The Economic Impact of Noise. Prepared by NBS, Washington, D.C., U.S. Government Printing Office, December 1971.

U.S. EPA, Office of Noise Abatement and Control, Noise Abatement and Control Policy of HUD. U.S. Government Printing Office, Washington, D.C., April 1977.

U.S. EPA, Office of Noise Abatement and Control, Noise Emission Standards for Construction Equipment (Background Document for Portable Air Compressors). EPA-550/9-76-004, U.S. Government Printing Office, Washington, D.C., December 1975. (2 copies, one on loan)

U.S. EPA, Office of Noise Abatement and Control, Noise Emission Standards for Construction Equipment Proposed Wheel and Crawler Tractor Noise Emission Regulation. Part 1 and 2, EPA-550/9-77-250, U.S. Government Printing Office, Washington, D.C., June 1977.

U.S. EPA, Office of Noise Abatement and Control, Noise Emission Standards for Surface Transportation Equipment Information in Support of the Proposed Regulation for Truck-Mounted Solid Waste Compactors Part 1 and 2. EPA550/9-77-204, U.Sj. Government Printing Office, Washington, D.C., August 1977.

U.S. EPA, Office of Noise Abatement and Control, Noise Source Regulation in State and Local Noise Ordinances. EPA-550/9-75-020, U.S. Government Printing Office, Washington, D.C., February 1975.

U.S. EPA, Office of Noise Abatement and Control, Toward a National Strategy for Noise Control. U.S. Government Printing Office, Washington, D.C., April 1977.

Urban Systems Research and Engineering, Inc., The Audible Landscape: A Manual for Highway Noise and Land Use, report prepared for the U.S. Department of Transportation, Federal Highway Administration, Office of Research and Development, November 1974.

Verve Research Corp., Colorado Springs, Colorado: Case History of a Municipal Noise Control Program. For EPA/ONAC, Washington, D.C., February 1979.

Verve Research Corp., Hillsborough County, Florida: Case History of a County Noise Control Program. For EPA/ONAC, Washington, D.C., August 1979.

Wyle Research Corp., San Diego California - Case History of Municipal Noise Control Program. For EPA/ONAC, Washington, D.C., November 1978.

Wyle Research. Insulation of Buildings against Highway Noise. Report prepared for the U.S. Department of Transportation, Federal Highway Administration, Office of Development, FHWA-TS-77-202, 1977.

Yaniv, S. L. and Flynn, D. R., Noise Criteria for Buildings: A Critical Review. NBS Special Publication 668.

Yerges, L. F., Sound Noise, and Vibration Control. 2nd Ed. Van Nostrand, New York, 1978.