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Analysis

SUBSTRATEGY FOR
CONSTRUCTION SITE NOISE ABATEMENT

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control

August 1980

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I. DESCRIPTION OF CONSTRUCTION NOISE

A. NATURE OF CONSTRUCTION

The construction industry is unique. No other industry has the same combination of labor, capital, laws, management, technical resources, and traditions. Construction takes place all over the United States in rural, suburban, and urban areas every day of the year, so noise reduction in this industry is a national problem. Fortunately the techniques for the reduction of construction noise also apply all of over the country, even though they may apply for only a short time in a particular location.

The outstanding difference between construction and other industries is that construction is, by definition, a temporary activity. There are very few construction projects that last several years. Even very large buildings and roads are under construction in a particular area for only a reasonably short time, seldom more than two years. The noise from such a project changes as the different phases of the construction are completed. Noise control programs that take a long time to mature or officials that are very slow to act usually find that the problem is gone by the time they are effective. A standard defense by the construction industry when charged with excessive noise is that soon it will be over, and even, "the noisier we are, the faster we are working, and the sooner you will have peace and quiet."

Because the projects are temporary, the involvement of the individuals who make the noise and direct the noise reduction efforts is also temporary. Usually the projects do not last long enough for the management and workers to become acquainted with the community in which the work is performed.

On many projects the labor force comes from out of town or from another neighborhood. Construction workers frequently commute tens of miles daily from their homes to a wide variety of work locations during a year. In addition it is common to organize companies specifically for the purpose of completing a particular project. In such cases, the legal responsibility and the reputation of the firm are short-lived and many legal and moral sanctions are only weakly applicable.

There are four steps in the construction projects: planning, design, construction, and follow up. Although almost all the noise is created in the third step the first two steps are very important places to inject noise control. Planning and design include not only the item that is to be constructed, but also the method of constructing it. Type of construction, kinds of equipment, site layout, times of operation, schedules for materials, and similar planning decisions can affect the noise that will be produced during the construction phase. Some of these techniques are developed in detail in Section III.

B. GEOGRAPHY OF CONSTRUCTION SITES

The problem of noise from construction activity depends on the geography of the construction site. Five classes of sites illustrate the range of noise conditions.

1. Remote, Large Area Sites

These include dams, major airfields, military bases, nuclear power plants, and mining facilities. They are so large that construction on one side of the site is unheard on the other side. They are almost always far removed from residential areas although a small number of residents on some sides of the site may be affected. These projects are the ones with the longest duration of construction.

2. Remote Linear Sites

These include railroads, rural highways, pipelines, and electrical power lines. The site may be fairly close to some scattered residences but the noise sources move along the length of the construction fairly rapidly as the project proceeds.

3 Urban, Moderate Area Sites

These include housing developments, shopping centers, large factories, and harbor improvements. The sites are located in densely populated areas and are small enough so that very noisy sources can be heard all around the site.

4. Urban Linear Sites

These include streets, canals, sewers, water and gas pipes, conduits, and overhead wires. Noise sources on the sites are very close to residences, but they move along quickly. Sources are audible on both sides of the site. For both urban and remote linear sites the movement of the construction activity along the site causes the noise exposure (number of people times the time they are exposed) for this kind of site to be similar to that of a more conventional site in the same area with the same duration.

5. Urban Concentrated Sites

These include office buildings, apartment houses, street repairs, and transportation terminals. They are very close to densely populated residential structures and all equipment used at the site can be heard horizontally and vertically.

Clearly noise reduction techniques that are appropriate for one kind of site may not be appropriate or effective for other kinds. In the later sections of this document the degree of their applicability is indicated.

C. PHASES OF CONSTRUCTION ACTIVITY

The kind of equipment, its duty cycle, and its location on the site change with the phase of construction activity. Most construction projects have five distinct phases that may involve different contractors, different operations, different working hours, and different locations on the site.

1. Demolition, Clearing, Grading, and Preparation

During this phase any existing structures are removed, the land is cleared of trees, rubble, and rocks, and access roads are scraped for later phases. The site is leveled, or contoured, test borings are made, drainage is provided, protective barriers are erected, and office and utility facilities are installed. Cranes, dozers, front end loaders, backhoes, graders pavement breakers, jack hammers, blasting, and trucks are used extensively.

2. Excavation

Holes are dug or blasted; cuts and fills are made; ditches, trenches and tunnels are dug; and drainage is provided. Cranes, trenchers, shovels, backhoes, pile drivers, dozers, loaders, and trucks are used extensively.

3. Placing Foundation

Ballast is installed, forms are erected, footings and walls are poured, concrete blocks or precast panels are set in place, and earth is compacted and backfilled to the foundations. Cranes, concrete mixers, compactors, backfillers, ballast settlers and tampers, concrete pumps, welders, and air compressors and trucks, are used extensively.

4. Erection of Structures or Putting Down of Pipes and Pavement

This is the phase that is normally thought of as construction. It uses the greatest variety of equipment, the largest number of people, and the longest time. Buildings are built, road surfaces are laid, pipes and cables are installed and covered, and large quantities of buiding materials are brought to the site, installed, and finished. All types of equipment are useo especially fixed and mobile cranes, tractors, conveyors, pavers, air compressors, concrete mixers, pavers, rollers, saws, generators, pneumatic wrenches, asphalt heaters, pumps, hand tools, and trucks.

5. Finishing and Clean Up

Waste is removed, topsoil is replaced, seed and landscaping are installed, utilities are connected, structures are washed and cleaned, and decoration is added. Tractors, loaders, mobile cranes, hand tools, air compressors, pumps, welders, and trucks are used extensively. Note that trucks are important for delivering and removing materials in every phase of almost every type of construction.

D. DIFFERENT CONSTRUCTION TECHNIQUES AND EQUIPMENT

Different construction jobs often can be done with different techniques that require quite different equipment. For example, a tunnel can be driven or it can be constructed from a cut and fill. If it is underwater, it often can be precast, towed to the site as a tube, sunk, and pumped dry. Buildings can be frame, masonry, steel, or poured concrete. Very different equipment will be used for the different methods. The major divisions of construction equipment are as follows:

1. Earthmoving

Dredges, drag lines, shovels, dozers, loaders, scrapers, graders earth augers, trenchers, backhoes, bucketwheel excavators, and both offroad and onroad trucks fall in this category.

2. Impactors

Ballast settlers and tampers, pile drivers, reciprocating compactors, pavement breakers, rock crushers, and jackhammers are the most common examples.

3. Materials Handling

Fixed and mobile cranes, derricks, concrete pumps, water pumps, conveyors, concrete mixers, pavers, asphalt spreaders, offroad and onroad trucks, tugs, railroads barges, and occasionally helicopters are included.

4. Miscellaneous

Generators, saws, pneumatic wrenches, riveters, drills, welders, asphalt heaters, and air compressors are the most numerous examples.

II. SEVERITY AND IMPACT OF CONSTRUCTION NOISE EXPOSURE

Prediction of the nationwide impact of construction noise requires detailed information and statistical distributions in three categories: construction equipment noise emissions, equipment usage on construction projects and sites, and locations and activities of hearers of the noise.

A. CONSTRUCTION EQUIPMENT NOISE EMISSIONS

Every piece of construction equipment has its own noise characteristic which differs from that of every other piece. The differences are caused by different drives (electric, diesel, gasoline, compressed air), different exhausts, different gear boxes and fans, different numbers and kinds of hydraulic systems, different propulsion (tracked or wheeled), and other differences. The same piece of equipment has different sound characteristics for its different modes of operation. Stationary equipment may idle, pump, mix, compress, saw, pound, generate, weld, etc.; moving equipment may idle, rotate, push or pull, lift or lower, climb or descend, go forward or backward, etc. Thus for each of the different makes, models, sizes, and ages of each of the many, many different types of construction equipment in use today, one needs to know the sound level at a known distance for each horizontal and vertical angle and for each mode of operation. Unfortunately these data are not available. Very rough approximations have been made in the case of some of the most common and noisiest equipments.

B. EQUIPMENT USAGE ON CONSTRUCTION PROJECTS AND SITES

Section I described some of the different kinds of construction projects and sites and implied the severity and duration of their effects on communities. Although the location of the equipment on the site of very large construction projects may make a little difference in the noise level at receiving properties, on concentrated urban sites about which the population is distributed very unevenly, the difference may be crucial to the effect on the community. The location of access roads will change the side of the site that receives and sends out the trucks that move earth and building materials; the location of service equipment such as portable air compressors and pumps will affect the residences and the passersby that receive noise from this equipment; the locations that are used to park equipment overnight will determine which residents will hear the engines when they are started and revved in the morning.

The number and types of construction equipment will vary widely depending on the nature of the construction project, its size, the size and shape of the site, the methods that are used, the equipment that is available, and the phase under consideration. The construction schedule also will affect the number and choice of equipment and its working cycles.

In regions of the nation in which there are strong seasonal differences in precipitation and temperature, there are significant seasonal trends in construction activity. Frozen aggregates make poor asphalt and concrete. Frozen or saturated soils are difficult and dangerous to work in. Wind and ice make it dangerous to work on open structures. Driving rain frequently makes it impossible to pour concrete out of doors and makes uncovered construction work too disagreeable to perform. These and other seasonal factors, such as the availability of transient labor, make pronounced differences in construction activities that show up when one tries to use year-round measures of noise levels to determine impacts on communities. Many construction projects are completed within one season, and they are not usefully measured by the normal 365-day, day-night, equivalent noise level.

The importance of a particular piece of equipment on the site will depend in part on the presence of other equipment. For instance, if during the demolition phase, a crane, a front loader, and a truck are operating, the crane noise may be so great that the other equipment does not contribute significantly to the overall noise level when they operate together. In the grading phase, the front loader may be the noisiest equipment on the site, and in the excavation phase the noise from a backhoe may dominate the noise level of the front loader and the trucks they are filling. Thus the contribution of the noise of each piece of equipment to the total noise from the construction activity depends not only on its noise characteristics, its mode of operation, its duty cycle, and its location, but on the relationship of all of these factors to those of all the other noisy equipment on the site.

The noise from a construction site, therefore, is a complex, constantly changing quantity. Each construction project and each site are different from all others. Unfortunately there are few current data on the numbers and locations of each type of construction project in a year, no statistical distributions of their physical size or duration, and no representative data from which one can compute the more subtle relationships among most of the pieces of equipment, their locations, and their usage. The data that are available have been used in the impact analyses in Section D below.

C. LOCATIONS AND ACTIVITIES OF THE POPULATION IMPACTED BY CONSTRUCTION NOISE

In order to calculate the impact of construction noise on the population, people's locations and activities relative to the construction must be known. Although, obviously urban and suburban construction sites will be the ones that have the greatest influence on people around them, some of the relationships are not obvious. Section D shows that smaller cities and urban fringes are the places where the exposures to noise impact are largest. In the case of urban sites, the neighbors may be in high buildings that receive no shielding fom the walls of the pit during the excavation phase and no benefit from the practice of manufacturers of modern equipment who reduce noise levels in the horizontal plane by redirecting the exhausts and other sources vertically. Furthermore, urban sites are frequently cramped and must use equipment such as backhoes and techniques such as shoring adjacent buildings, that are unnecessary and less noisy in other locations.

It is common to classify the impact of construction noise in terms of its effects on hearing, its interference on speech communication, its interference on sleep, and the general overall annoyance it produces. Residents are the population for whom the impact is most often considered, but the effects of the noise on students, offsite workers, and passersby also are important. All these people are not at the same locations throughout the construction periods, so the times of their varying distances and directions from the sources on the site must be compared with the times of the operation of the different pieces of construction equipment to determine the exposure of the hearers as a function of time.

If the people are indoors or otherwise partially shielded from the construction noise, their exposure to the noise will be reduced by the reduction afforded by the shielding. If they are engaged in noisy activities the impact of the construction noise will be limited to its contribution to the total noise level at the listener.

The risk to hearing caused by construction noise lasts as long as the construction noise persists, but the interference with speech or sleep is confined to the periods in which the hearers are trying to converse or are listening to radio or television, and in which they are trying to sleep. These interferences and the overall annoyance are closely connected to the number of times per hour or day that a single event of peak noise level exceeds the listener's ambient noise level by a significant amount.

The time history of the hearers and their sensitivities to the effects of noise should be correlated with the time history of the noise at the hearers' locations. Unfortunately the data do not exist that will permit a good estimation of the time and location distributions of the population, their activities, and their ambient sound levels.

D. ESTIMATES OF THE RELATIVE EXPOSURE OF POPULATIONS TO CONSTRUCTION NOISE

1. Relative Exposures to Construction Activity

Section I describes the nature of construction, the importance of the geography of construction sites, the phases of activity at each site, and the different construction techniques and equipment. The variety of construction and the variability of its timing make it very difficult to predict the benefits that will be obtained from different alternate national noise strategies for this industry.

The preceding parts of this section explained the requirements for data to predict the nationwide impact of noise from construction sites. Of course, these data are not available and analyzing them would be a nearly impossible job if there were such data, so simplifications and approximations must be made.

Intensive efforts were made to obtain reliable estimates and approximations during the preparation of the background documents for proposed regulations for the noise from air compressors and wheel and crawler tractors*. The data in these documents have been used to estimate relative exposures to noise from activities at construction sites to help in developing a national strategy for the control and abatement of such noise.

The data necessary to determine the number of people exposed to the noise from each type of construction equipment are not available. One cannot determine the number from the population density of the areas in which the sites are located. One needs to know the density immediately around each site, the site size, and configuration. However, one can infer the relative population exposure from the population density information that has been collected. Comparisons of such relative populations

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**Noise Emission Standards for Construction Equipment, Background Document for Portable Air Compressors, U.S. Environmental Protection Agency, December 1975. EPA 550/9-76-004.*

Noise Emission Standards for Construction Equipment, Proposed Wheel and Crawler Tractor Noise Emission Regulation, U.S. Environmental Protection Agency, June 1977. EPA 550/9-77-250.

exposures are valid if the various pieces of equipment and their usage are distributed and used the same way in the same demographic areas.

Exhibit II-1 has been taken from an earlier report[1], but was used in the background document for tractors. The upper table shows the average population density for five demographic categories in which construction projects are common and for four types of construction projects. The authors explain:

> For the purpose of gathering and analyzing population and construction site statistics, we divided the U.S. into five regions. These regions are based on those defined by the U.S. Bureaus of the Budget (31) and the Census (32). A key to understanding the rationable used for establishing these regions is the concept of Standard Metropolitan Statistical Area (SMSA). A SMSA is a group of continuous counties which contains at least one central city of 50,000 inhabitants or more. There are 233 SMSA containing 65 percent of the nation's population and about 10 percent of the land area. The population density in the nonmetropolitan areas is too low to create much construction noise exposure or to allow meaningful computation of the exposure that does exist. This study, therefore, restricts itself to construction occuring within the SMSA's.[2]

Two different population densities were applied to the various types of construction. The first is the residential density which was applied to residential and urban public works projects. The second was the working day population density, which was applied to the nonresidential and industrial construction projects.

The four types of construction were based on the division of construction by the U.S. Bureau of the Census at the time the construction activity was monitored and counted. (Today the Census uses a different categorization which makes comparisons with the older data difficult.) The four types are defined as follows:

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[1] *"Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances," Bolt, Beranek and Newman, EPA document NTID300.1, December 31, 1971.*

[2] *Ibid p. 71.*

Population Density (People per Square Mile)

	Large High Density Central Cities	Large Low Density Central Cities	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	15,160	4,410	3,710	3,380	125
Non-Residential	16,650	4,860	4,070	3,100	114
Industrial/ Commercial	16,650	4,860	4,070	3,100	114
Public Works	15,160	4,410	3,710	3,380	125

Number of Sites

	Large High Density Central Cities	Large Low Density Central Cities	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	8,708	21,578	102,559	262,800	118,779
Non-Residential	390	980	2,404	6,183	2,752
Industrial/ Commercial	1,561	3,922	9,617	24,731	11,006
Public Works	3,184	25,120	96,600	134,920	252,400

EXHIBIT II-1: POPULATION DENSITIES AND NUMBERS OF SITES

Residential includes single and multifamily housing.

Nonresidential includes hotels, motels, dormitories and other nonhousekeeping residential structures; offices, banks; government administrative buildings; hospital and institutional care buildings; libraries, museums, art galleries, and educational buildings; and public work buildings.

Industrial includes industrial buildings and warehouses; religious buildings; recreational, social, and amusement buildings; mercantile stores; restaurants; and automobile parking garages, service stations, and repair facilities.

Urban Public Works includes all nonbuilding construction such as streets, street repairs, power and communication lines, water pipes, sewers, and conservation construction. (State and Federal projects are omitted.)

The lower table of Exhibit II-1 shows the average number of construction sites for each of the types of construction in each demographic category.

Exhibit II-2 shows the results when the numbers in the same cells of the two tables in Exhibit II-1 are multiplied together. The products are a rough measure of the potential exposure of the nation's population to construction activity, the effects of which include traffic congestion, changes in water runoff, dust, and noise while the construction is in progress and longer term changes in demography, economy, and land use. Because the high density central cities have fewer construction sites, the products of the sites and the population density are similar to the products in lower density demographic areas with more sites. In residential construction the urban fringe areas have a higher product than the sum of the products of all the other demographic areas. Nonresidential and industrial construction are minor in comparison with the residential and public works construction activities. In the field of urban public works the products increase steadily as the population density decreases, all the way to the urban fringe. This is to be expected because of the road and utility construction activity associated with thinly spread populations. It seems clear that the demographic areas with the greatest potential exposure to construction activity, are the smaller SMSA's and the urban fringes, largely because of the large amount of residential construction and the supporting public works.

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe	Total
Residential	132	95	380	888	15	1510
Nonresidential	6	5	10	19	-	40
Industrial	26	19	39	77	1	162
Urban Public Works	48	111	357	456	31	1003
Total	212	230	786	1440	47	2715

(Numbers are in millions)

EXHIBIT II-2: PRODUCTS OF POPULATION DENSITIES AND NUMBERS OF SITES

2. Relative Usage of Various Construction Equipment

Exhibits II-3 to II-6 are reproduced from the air compressor background document. They show, for each of four types of construction activity that is common in built up areas, the average sound level at 50 feet from each of the types of equipment used in ordinary construction. They also show the fraction of the time that each type of equipment is actually in use during each phase of the construction process. The average duration, in hours, of each phase is shown at the bottom of each table. The background document for tractors reproduced these tables, except that the categories of "dozer" and "loader" were broken into five categories as follows:

- Crawler tractor, less than 200 horsepower (called small here)
- Crawler tractor, more than 200 horsepower (called large here)
- Wheel loader, less than 250 horsepower (called small here)
- Wheel loader, more than 250 horsepower (called large here)
- Wheeled tractor

Exhibit II-7 shows the results of multiplying the hours of duration of the construction phases by the usage factors for the various types of equipment. Where two pieces of equipment of the same type were used, the time of their usage has been doubled. In the latter steps of this analysis all the phases of construction have been aggregated, and only the total time of usage per site of each piece of equipment has been used. Exhibit II-8 shows these total hours by type of site.

Multiplication of the data in Exhibit II-8 by the number of sites in Exhibit II-1 will give the total number of hours of operation of each type of equipment at sites in each type of demographic area. A further multiplication by the population density of each of these demographic areas will give a measure of the relative national population exposure for each type of equipment. Exhibit II-9 shows the results of these multiplications summed over all demographic areas. The numbers in the cells of this exhibit indicate the <u>relative</u> <u>potential</u> exposure the population has to the noise from each type of equipment.

It is important to note that these are only relative measures and not absolute numbers of people exposed to some particular level of sound. They represent the national average number of <u>hours</u> that a particular piece of equipment is operated weighted by

(text continued on page 26)

Equipment		Construction phase					Leq (50') during work periods for each item, over one project
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	-	0.1	-	-	0.25	68.7
Backhoe	(85)·	0.02	0.2	-	-	0.02	69.5
Concrete mixer	(85)·	-	-	0.4	0.08	0.16	76.5
Concrete pump	(82)·	-	-	-	-	-	-
Concrete vibrator	(76)	-	-	-	-	-	-
Crane, derrick	(88)·	-	-	-	-	-	-
Crane, mobile	(83)·	-	-	-	0.10	0.04	69.5
Dozer	(87)·	0.10	0.1	-	-	0.04	72.0
Generator	(78)	0.4	-	-	-	-	64.5
Grader	(85)·	0.05	-	-	-	0.02	65.0
Paving Breaker	(88)·	-	-	-	-	0.01	61.0
Loader	(84)·	0.2	0.1	-	-	0.04	70.0
Paver	(89)·	-	-	-	-	0.025	66.0
Pile driver	(101)·	-	-	-	-	-	-
Pneumatic tool	(85)·	-	-	0.04	0.1	0.04	72.5
Pump	(76)	-	0.1	0.2	-	-	63.0
Rock drill	(98).	-	0.005	-	-	-	65.5
Roller	(80)·	-	-	-	-	0.04	59.0
Saw	(78)	-	-	0.04[2]**	0.1[2]	0.04[2]	68.5
Scraper	(88)·	0.05	-	-	-	0.01	67.0
Shovel	(82)·	-	0.2	-	-	-	65.5
Truck	(88)·	0.04	0.1	-	-	0.04	70.0
		L_{eq} (50') per site during work periods =					82.0 dBA
Hours at site		24	24	40	80	40 Σ =	208 hrs. = 26 days

Total number of sites = 514,424 (Table IV(a) of reference 32)

* Numbers in parentheses ( ) represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [ ] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

EXHIBIT II-3: NOISE LEVELS AND USAGE FACTORS OF EQUIPMENT IN DOMESTIC HOUSING CONSTRUCTION

Equipment		Construction phase					$L_{eq(50')}$ during work periods for each item, over one project
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	-	1.0[2]**	1.0[2]	1.0[2]	0.4[2]	83.5
Backhoe	(85)	0.04	0.16	0.4	-	0.04	76.5
Concrete mixer	(85)	-	-	0.4	0.4	0.16	79.0
Concrete pump	(82)	-	-	0.08	0.4	0.08	74.5
Concrete vibrator	(76)	-	-	0.2	0.2	0.04	67.0
Crane, derrick	(88)	-	-	-	0.16	0.04	76.0
Crane, mobile	(83)	-	-	-	0.16[2]	0.04[2]	74.0
Dozer	(87)	0.16	0.4	-	-	0.16	78.0
Generator	(78)	0.4[2]	1.0[2]	-	-	-	75.0
Grader	(85)	0.08	-	-	-	0.02	63.5
Paving breaker	(88)	-	0.1	0.04	0.04	0.04	75.0
Loader	(84)	0.16	0.4	-	-	0.16	75.0
Paver	(89)	-	-	-	-	0.1	70.0
Pile driver	(101)	-	-	0.04	0.16[2]	0.04[2]	85.0
Pneumatic tool	(85)	-	-	0.04	0.16[2]	0.04[2]	76.0
Pump	(76)	-	1.0[2]	1.0[2]	0.4	-	76.5
Rock drill	(98)	-	0.04	-	-	0.005	78.0
Roller	(80)	-	-	-	-	0.1	60.5
Saw	(78)	-	-	0.04[3]	1.0[3]	-	76.5
Scraper	(88)	0.55	-	-	-	-	73.0
Shovel	(82)	-	0.4	-	-	-	72.0
Truck	(88)	0.16[2]	0.4	-	-	0.16	80.0
		$L_{eq(50')}$ per site during work periods =					91.0 dBA
Hours at site		80	320	320	480	160 Σ =	1360 hrs.
						=	170 days

Total number of sites = 12,710 (Tables IV(h) of reference 32)

* Numbers in parentheses ( ) represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [ ] represent average number of items if number is greater than one. Blanks indicate zero or very rare usage.

EXHIBIT II-4: NOISE LEVELS AND USAGE FACTORS OF EQUIPMENT IN NONRESIDENTIAL CONSTRUCTION ($190K-4000K)

Equipment		Construction phase					Leq(50') during work periods for each item, over one project
		Clearing	Excavation	Foundation	Erection	Finishing	
Air compressor	(81)*	-	1.0	0.4	0.4	0.4	78.0
Backhoe	(85)	0.04	0.16	0.4	-	0.04	76.5
Concrete mixer	(85)	-	-	0.4	0.16	0.16	77.5
Concrete pump	(82)	-	-	0.05	0.16	0.08	71.0
Concrete vibrator	(76)	-	-	0.2	0.1	0.04	65.5
Crane, derrick	(88)	-	-	-	0.04	0.02	70.0
Crane, mobile	(83)	-	-	-	0.08	0.04	68.0
Dozer	(87)	0.2	0.4	-	-	0.04	77.5
Generator	(78)	0.4	0.4	-	-	-	68.5
Grader	(85)	0.05	-	-	-	0.02	62.5
Paving breaker	(88)	-	0.1	0.04	0.04	0.04	75.0
Loader	(84)	0.16	0.4	-	-	0.04	74.5
Paver	(89)	-	-	-	-	0.12	70.5
Pile driver	(101)	-	-	0.04	-	-	81.0
Pneumatic tool	(85)	-	-	0.04	0.1[3]**	0.04	76.0
Pump	(76)	-	0.4	1.0[2]	0.4	-	53.0
Rock drill	(98)	-	0.02	-	-	0.003	75.0
Roller	(80)	-	-	-	-	0.1	60.5
Saw	(78)	-	-	0.04[2]	0.1[2]	-	67.5
Scraper	(88)	0.14	-	-	-	0.08	70.5
Shovel	(82)	-	0.4	-	-	0.06	72.0
Truck	(88)	0.16[2]	0.26[2]	-	-	0.16	78.5

$L_{eq(50')}$ per site during work periods = 88.0 dBA

Hours at site	80	320	320	480	160Σ	= 1360 hrs. = 170 days

Total number of sites = 50,539 (Tables IV(c) of reference 32)

* Numbers in parentheses ( ) represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [ ] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

EXHIBIT II-5: NOISE LEVELS AND USAGE FACTORS OF EQUIPMENT IN INDUSTRIAL CONSTRUCTION
($30K-820K, no high-rise)

Equipment		Construction phase: Clearing	Excavation	Foundation	Erection	Finishing	$L_{eq(50')}$ during work periods for each item, over one project
Air compressor	(81)*	1.0	1.0	0.4	0.4	0.4[2]**	79.0
Backhoe	(85)	0.04	0.4	-	-	0.16	74.5
Concrete mixer	(85)	-	-	0.16[2]	0.4[2]	0.16[2]	81.0
Concrete pump	(82)	-	-	-	-	-	-
Concrete vibrator	(76)	-	-	-	-	-	-
Crane, derrick	(88)	-	0.1	0.04	0.04	-	74.0
Crane, mobile	(83)	-	-	-	0.16	-	69.5
Dozer	(87)	0.3	0.4	0.2	-	0.16	79.5
Generator	(78)	1.0	0.4	0.4	0.4	0.4	75.0
Grader	(85)	0.08	-	-	0.2	0.08	74.0
Paving breaker	(88)	0.5	0.5	-	0.04	0.1[2]	80.5
Loader	(84)	0.3	0.3	0.2	-	0.16	76.0
Paver	(89)	-	-	0.1	0.5	-	81.5
Pile driver	(101)	-	-	-	-	-	-
Pneumatic tool	(85)	-	-	0.04[2]	0.1	0.04	72.5
Pump	(76)	-	0.4[2]	1.0[2]	0.4[2]	-	75.5
Rock drill	(98)	-	0.02	-	-	-	82.5
Roller	(80)	-	-	0.01	0.5	0.5	73.5
Saw	(78)	-	-	0.04[2]	0.04	-	63.5
Scraper	(88)	0.08	-	0.2	0.08	0.08	78.0
Shovel	(82)	0.04	0.4	0.04	-	0.04	71.0
Truck	(88)	0.16[2]	0.16	0.4[2]	0.2[2]	0.16[2]	84.5
		$L_{eq(50')}$ per site during work periods =					91.0 dBA
Hours at site:		12	12	24	24	12 Σ =	84 hrs.
						=	10 ½ days

Total number of sites = 485,224 (Table IV(d) of reference 32)

* Numbers in parentheses ( ) represent average noise levels (dBA) at 50 ft.
** Numbers in brackets [ ] represent average number of items in use, if that number is greater than one. Blanks indicate zero or very rare usage.

EXHIBIT II-6: NOISE LEVELS AND USAGE FACTORS OF EQUIPMENT IN PUBLIC WORKS CONSTRUCTION

(Municipal streets and sewers)

	Clearing	Excavation	Foundation	Erection	Finishing	Total
AIR COMPRESSOR						
Domestic	-	2.4	-	-	10	12.4
Nondomestic	-	640	640	960	28	2368
Industrial	-	320	128	192	64	704
Urban Public Works	12	12	9.6	9.6	9.6	52.8
BACKHOE						
Domestic	.5	4.3	-	-	.5	5.3
Nondomestic	3.2	51.2	128	-	6.4	188.8
Industrial	3.2	51.2	128	-	6.4	138.8
Urban Public Works	.5	4.8	-	-	1.9	7.2
CONCRETE MIXES						
Domestic	-	-	16	6.4	6.4	28.8
Nondomestic	-	-	128	192	25.6	345.6
Industrial	-	-	128	76.8	25.6	230.4
Urban Public Works	-	-	7.7	19.2	3.8	30.7
CONCRETE PUMP						
Domestic	-	-	-	-	-	-
Nondomestic	-	-	25.6	192	12.8	230.4
Industrial	-	-	16	76.8	12.8	105.6
Urban Public Works	-	-	-	-	-	-
CONCRETE VIBRATOR						
Domestic	-	-	-	-	-	-
Nondomestic	-	-	64	96	6.4	166.4
Industrial	-	-	64	48	6.4	118.4
Urban Public Works	-	-	-	-	-	-
CRANE, DERRICK						
Domestic	-	-	-	-	-	-
Nondomestic	-	-	-	76.8	6.4	83.2
Industrial	-	-	-	19.2	3.2	22.4
Urban Public Works	-	1.2	1.0	1.0	-	3.2

EXHIBIT II-7: AVERAGE USAGE BY PHASE, HOURS, PER SITE, FOR CONSTRUCTION EQUIPMENT

	Clearing	Excavation	Foundation	Erection	Finishing	Total
MOBILE CRANE						
Domestic	-	-	-	8	1.6	9.6
Nondomestic	-	-	-	153.2	12.8	166.0
Industrial	-	-	-	38.4	6.4	44.8
Urban Public Works	-	-	-	3.8	-	3.8
DOZER						
Domestic	2.4	2.4	-	-	1.6	6.4
Nondomestic	12.8	128	-	-	25.6	166.4
Industrial	16	128	-	-	6.4	150.4
Urban Public Works	3.6	4.8	4.8	-	1.9	15.1
GENERATOR						
Domestic	9.6	-	-	-	-	9.6
Nondomestic	64	640	-	-	-	704
Industrial	32	128	-	-	-	160
Urban Public Works	12	4.8	9.6	9.6	4.8	40.8
GRADER						
Domestic	1.2	-	-	-	.8	2.0
Nondomestic	6.4	-	-	-	3.2	9.6
Industrial	4.0	-	-	-	3.2	7.2
Urban Public Works	1.0	-	-	4.8	1.0	6.8
PAVING BREAKER						
Domestic	-	-	-	-	0.4	0.4
Nondomestic	-	32	12.8	19.2	6.4	70.4
Industrial	-	32	12.8	19.2	6.4	70.4
Urban Public Works	6	6	-	1	2.4	15.4
LOADER						
Domestic	4.8	2.4	-	-	1.6	8.8
Nondomestic	12.8	128	-	-	25.6	166.4
Industrial	12.8	128	-	-	6.4	147.2
Urban Public Works	3.6	3.6	4.8	-	1.9	13.9

EXHIBIT II-7: AVERAGE USAGE BY PHASE, HOURS, PER SITE, FOR CONSTRUCTION EQUIPMENT (cont.)

	Clearing	Excavation	Foundation	Erection	Finishing	Total
			PAVER			
Domestic	-	-	-	-	1	1
Nondomestic	-	-	-	-	16	16
Industrial	-	-	-	-	19.2	19.2
Urban Public Works	-	-	2.4	12	-	14.4
			PILE DRIVER			
Domestic	-	-	-	-	-	-
Nondomestic	-	-	12.8	102.4	12.8	128
Industrial	-	-	14.1	-	-	14.1
Urban Public Works	-	-	-	-	-	-
			PNEUMATIC TOOL			
Domestic	-	-	1.6	8	1.6	11.2
Nondomestic	-	-	12.8	102.4	12.8	128
Industrial	-	-	14.1	144	6.4	164.5
Urban Public Works	-	-	19.2	2.4	0.5	22.1
			ROCK DRILL			
Domestic	-	0.1	-	-	-	0.1
Nondomestic	-	12.8	-	-	0.8	13.6
Industrial	-	6.4	-	-	.5	6.9
Urban Public Works	-	0.2	-	-	-	0.2
			ROLLER			
Domestic	-	-	-	-	1.6	1.6
Nondomestic	-	-	-	-	16	16
Industrial	-	-	-	-	16	16
Urban Public Works	-	-	0.2	12	6	18.2
			SAW			
Domestic	-	-	3.2	16	3.2	22.4
Nondomestic	-	-	38.4	1440	-	1478.4
Industrial	-	-	25.6	96	-	121.6
Urban Public Works	-	-	1.9	1.0	-	2.9

EXHIBIT II-7: AVERAGE USAGE BY PHASE, HOURS, PER SITE, FOR CONSTRUCTION EQUIPMENT (cont.)

	Clearing	Excavation	Foundation	Erection	Finishing	Total
			SCRAPER			
Domestic	1.2	-	-	-	0.4	1.6
Nondomestic	44	-	-	-	-	44
Industrial	11.2	-	-	-	12.8	24
Urban Public Works	1.0	-	4.8	1.9	1.0	8.7
			SHOVEL			
Domestic	-	4.8	-	-	-	4.8
Nondomestic	-	128	-	-	-	129
Industrial	-	128	-	-	9.6	137.6
Urban Public Works	0.5	4.3	1.0	-	0.5	6.3
			TRUCK			
Domestic	1.0	2.4	-	-	1.6	5.0
Nondomestic	25.6	128	-	-	25.6	179.2
Industrial	25.6	166.4	-	-	25.6	217.6
Urban Public Works	3.8	1.9	19.2	9.6	3.8	38.3
			CRAWLER TRACTOR < 200 HP			
Domestic	31.2	22.8	-	-	15.2	69.2
Nondomestic	39.2	377.6	-	-	73.6	490.4
Industrial	0.8	22.4	-	-	1.1	24.3
Urban Public Works	5.0	6.1	6.7	-	2.4	20.2
			CRAWLER TRACTOR > 200 HP			
Domestic	1.4	1.0	-	-	0.8	3.2
Nondomestic	7.2	70.4	-	-	14.4	92.0
Industrial	0.3	2.6	-	-	1.1	4.0
Urban Public Works	0.4	0.5	0.5	-	0.2	1.6
			WHEEL LOADER < 250 HP			
Domestic	14.6	7.2	-	-	4.8	26.6
Nondomestic	14.0	134.4	-	-	25.6	174.0
Industrial	3.2	32	-	-	1.4	36.6
Urban Public Works	5.8	5.8	7.7	-	2.7	22

EXHIBIT II-7: AVERAGE USAGE BY PHASE, HOURS, PER SITE, FOR CONSTRUCTION EQUIPMENT (cont.)

	Clearing	Excavation	Foundation	Erection	Finishing	Total
		WHEEL LOADER > 250 HP				
Domestic	3.3	1.9	-	-	1.2	6.9
Nondomestic	3.2	28.8	-	-	6.4	38.4
Industrial	0.4	6.4	-	-	0.2	7.0
Urban Public Works	-	-	-	-	-	-
		WHEEL TRACTOR				
Domestic	41.3	20.9	-	-	14.0	76.2
Nondomestic	24.0	232.0	-	-	44.8	300.8
Industrial	19.2	182.4	-	-	8.0	209.6
Urban Public Works	12.7	12.5	33.6	-	6.2	65.0

EXHIBIT II-7: AVERAGE USAGE BY PHASE, HOURS, PER SITE, FOR CONSTRUCTION EQUIPMENT (cont.)

	Sound Level	Residential	Non-Residential	Public Industrial	Urban Public Works
Air Compressor	81	12	2368	704	53
Backhoe	85	6	189	189	7
Concrete Mixer	85	30	346	230	31
Concrete Pump	82	-	230	106	-
Concrete Vibrator	76	-	166	118	-
Crane, Derrick	88	-	83	22	3
Crane, Mobile	83	10	166	45	4
Generator	78	10	704	160	41
Grader	85	2	10	7	7
Paver	89	1	16	19	14
Paving Breaker	88	-	70	70	15
Pile Driver	101	-	128	14	-
Pneumatic Tool	85	11	128	165	22
Rock Drill	98	-	14	7	-
Roller	80	2	16	16	18
Saw	78	22	1478	121	3
Scraper	88	2	44	24	9
Shovel	82	5	128	138	7
Truck	88	5	180	218	38
Dozer	87	6	166	150	15
Loader	84	9	166	147	14
Crawler Tractor, small	80	70	490	24	20
Crawler Tractor, Large	83	3	92	4	2
Loader, small	82	27	174	37	22
Loader, large	84	7	38	7	-
Wheel Tractor	77	76	301	210	65

EXHIBIT II-8: NATIONAL AVERAGE USAGE, HOURS PER SITE FOR VARIOUS TYPES OF CONSTRUCTION EQUIPMENT AND DIFFERENT KINDS OF CONSTRUCTION PROJECTS

	Residential	Non-Residential	Industrial	Urban Public Works
Air Compressor	18.12	94.72	114.048	53.159
Backhoe	9.06	7.56	30.618	7.021
Conrete Mixer	45.3	13.84	37.26	31.093
Concrete Pump	-	9.2	17.176	-
Concrete Vibrator	-	6.64	19.116	-
Crane, Derrick	-	3.32	3.564	3.009
Crane, Mobile	15.1	6.64	7.290	4.012
Generator	15.1	28.16	25.92	41.123
Grader	3.02	0.4	1.134	7.021
Paver	1.51	0.64	3.078	14.042
Paving Breaker	-	2.8	11.340	15.045
Pile Driver	-	5.12	2.268	-
Pneumatic Tool	16.61	5.12	26.73	22.066
Rock Drill	-	0.56	1.134	-
Roller	3.02	0.64	2.592	18.054
Saw	33.22	59.12	19.602	3.009
Scraper	3.02	1.76	3.888	9.027
Shovel	7.55	5.12	22.356	7.021
Truck	7.55	7.2	35.316	38.114
Dozer	9.06	6.64	24.3	15.045
Loader	13.59	6.64	23.814	14.042
Crawler Tractor, small	105.7	19.6	3.888	20.06
Crawler Tractor, large	4.53	3.68	0.648	2.006
Loader, small	40.77	6.96	5.994	22.066
Loader, large	10.57	1.52	1.134	-
Wheel Tractor	114.76	12.04	34.02	65.195

EXHIBIT II-9: RELATIVE POTENTIAL POPULATION EXPOSURE TO EQUIPMENT OPERATIONS FOR VARIOUS TYPES OF CONSTRUCTION EQUIPMENT AND DIFFERENT KINDS OF CONSTRUCTION PROJECTS the average number of people who live in a square mile where such construction equipment activity is likely. Therefore, this is a measure of relative potential population exposure to equipment operations, but it does not indicate that this number of people actually will hear the equipment, nor does it indicate the effect that the noise from the equipment will have, if it is heard.

3. Relative Potential Noise Exposures to Various Construction Equipment

One of the objectives of EPA's noise abatement program is to eliminate exposure to community noise which is characterized by an L_{dn} of 75 dB or more. The average noise levels listed in the tables are measured at 50 feet, and construction equipment is seldom operated closer to hearers in the community than that distance, at least not for very long. Therefore, the amount by which the average sound level of a type of equipment exceeds 75 dB at 50 feet has been used as an index of the equipment's potential impact on the community. The first column in Exhibit II-10 shows the number of decibels by which the equipment's average sound level exceeds 75 dB. The other columns show the product of this number and the potential population exposure from Exhibit II-8. The entries in Exhibit II-10 represent a measure of the relative potential national noise impact of each type of equipment. Hence these are measures of relative potential annoyance, intrusiveness, and effect on health and welfare. The entries have been termed "relative potential noise exposures."

In the righthand column, the totals for all kinds of construction projects show that the most important contributors are, in order with their percentage contribution to the total for all equipment, as follows*:

air compressors**	14%	dozer	6%
concrete mixers	11%	backhoe	5%
trucks	10%	small loader	5%
small crawler tractors	6%	loader	5%
pneumatic tools	6%	wheel tractor	4%

The rank order of the various pieces of equipment will remain the same if a threshold other than 75 dB is chosen, but the relative magnitude of the potential exposures will change.

***The measurements upon which these percentages are based were made before any construction equipment was subject to Federal noise emission regulations.*

	Sound Level at 50' minus 75 dB	Relative Potential Noise Exposure				
		Residential	Nonresidential	Industrial	Urban Public Works	Total for all Construction
Air Compressor	+6	109	568	684	319	1680
Backhoe	+10	90	76	306	70	542
Concrete Mixer	+10	453	138	373	311	1275
Concrete Pump	+7	-	64	120	-	184
Concrete Vibrator	+1	-	7	19	-	26
Crane, Derrick	+13	-	43	46	39	128
Crane, Mobile	+8	121	53	58	32	264
Generator	+3	45	84	78	123	330
Grader	+10	30	4	11	70	115
Paver	+4	21	9	43	197	270
Paving Breaker	+3	-	36	147	196	379
Pile Driver	+26	-	133	59	-	192
Penumatic Tool	+10	166	51	267	221	705
Rock Drill	+23	-	13	26	-	39
Roller	+5	15	3	13	90	121
Saw	+3	100	177	59	9	345
Scraper	+13	39	23	51	117	230
Shovel	+7	53	36	156	49	294
Truck	+13	98	94	459	495	1146
Dozer	+12	109	80	292	181	662
Loader	+9	122	60	214	126	522
Crawler Tractor, small	+5	529	98	19	100	746
Crawler Tractor, large	+8	36	29	5	16	86
Loader, small	+7	285	49	42	154	530
Loader, large	+9	95	14	10	-	119
Wheel Tractor	+2	230	24	68	130	452
						11,490

EXHIBIT II-10: RELATIVE POTENTIAL NOISE EXPOSURE (ABOVE 75 DB AT 50 FEET) OF THE POPULATION FOR VARIOUS TYPES OF CONSTRUCTION EQUIPMENT AND DIFFERENT KINDS OF CONSTRUCTION PROJECTS

The dozers and loaders from the air compressor document overlap the tractors and loaders from the tractor document, but both are included to indicate the reasonable consistency of the data from two sources. The inclusion of the backhoe is consistent with the surprisingly high ranking this equipment received in an entirely independent report published by the National Highway Traffic Safety Administration*.

Note that trucks and truck mounted concrete mixers account for about one-fifth of the total relative potential noise exposure. Most concrete mixers are truck mounted and the engine that drives the mixer also drives the truck. (Few fixed batch concrete mixing plants are used on construction sites except for the mixers used in highway construction. These are a form of paver and are classified as a separate piece of equipment.)

The differences between the relative potential noise exposures of various types of equipment depending upon the type of construction are the reason that this separation has been retained throughout the analysis while other aggregations have been made. The differences have an impact on strategy. For example, State and local governments and utility companies licensed by the governments do most of the urban public works either directly or through contractors. Their control over noise on such sites and projects is relatively direct, and equipment that uniquely have high contributions to potential noise exposure on such projects, such as pavers, paving breakers, and scrapers, may be controlled best by States and local governments.

4. Relative Exposure of Demographic Categories to Various Types of Construction Equipment

In the previous section the different demographic categories were aggregated to clarify the relationship between equipment usage and population exposure. To estimate the feasibility of strategies that require State and local enforcement or that require communication of noise control information about particular equipment, it is desirable to calculate the number of hours each type of equipment operates in each demographic category. Exhibit II-11 shows the results of multiplying the hours of usage of each type of equipment from Exhibit II-9 by the number of sites in each demographic category from the lower table in Exhibit II-1. The results of these multiplications indicate the total number of hours of use annually of each piece of equipment in each demographic category.

(text continued on page 36)

Toth, William J., "Noise Abatement Techniques for Construction Equipment," Society of Automotive Engineers, August 1979. Final report prepared for U.S. Department of Transportation, DOT-TSC-NHTSA-79-45.

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	104,496	258,936	1,230,708	3,153,600	1,425,348
Nonresidential	923,520	2,320,640	5,692,672	14,641,344	6,516,736
Industrial	11,721,600	3,421,440	2,865,280	2,182,400	80,256
Urban Public Works	303,480	233,730	196,630	179,140	6,525

AIR COMPRESSORS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	52,248	129,468	615,354	1,576,800	712,674
Nonresidential	73,710	185,220	454,356	1,168,587	520,128
Industrial	295,029	741,258	1,817,613	4,674,159	2,081,134
Urban Public Works	22,288	175,840	676,200	944,400	1,766,800

BACKHOES

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	261,240	647,340	3,076,770	7,884,000	3,563,370
Nonresidential	134,940	339,080	831,784	2,139,318	952,192
Industrial	359,030	902,060	2,211,910	5,688,130	2,531,380
Urban Public Works	98,704	778,720	2,994,600	4,182,520	7,324,400

CONCRETE MIXERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	89,700	225,400	552,920	1,422,090	632,960
Industrial	165,466	415,732	1,019,402	2,621,486	1,166,636
Urban Public Works	-	-	-	-	-

CONCRETE PUMPS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	64,740	162,680	399,064	6,026,378	456,832
Industrial	184,198	482,796	1,134,806	2,918,258	1,298,708
Urban Public Works	-	-	-	-	-

CONCRETE VIBRATORS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	32,370	81,340	199,532	513,199	228,416
Industrial	34,342	36,294	211,574	544,082	242,132
Urban Public Works	9,552	75,360	289,800	404,760	757,200

CRANES, DERRICK

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	87,080	215,780	1,025,580	2,628,000	1,187,730
Nonresidential	64,740	162,680	5,779,216	14,863,932	6,615,308
Industrial	70,245	176,490	432,765	1,112,395	495,270
Urban Public Works	12,736	100,430	386,400	539,680	1,009,600

CRANES, MOBILE

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	87,080	215,780	1,025,590	2,628,000	1,187,790
Nonresidential	274,560	689,920	1,692,416	4,352,332	1,937,408
Industrial	249,760	627,520	1,538,720	3,956,960	1,760,880
Urban Public Works	130,544	1,029,920	3,860,600	5,331,720	10,348,400

GENERATORS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	17,416	43,156	205,118	525,600	237,558
Nonresidential	3,900	9,800	24,040	61,830	27,520
Industrial	10,927	27,454	67,319	173,119	77,042
Urban Public Works	22,288	175,840	676,200	944,440	1,766,900

GRADERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	8,708	21,578	102,559	262,800	113,779
Nonresidential	6,240	15,680	38,464	98,928	44,032
Industrial	29,659	74,513	182,723	469,889	209,114
Urban Public Works	44,576	351,680	1,352,400	1,888,880	3,533,600

PAVERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	27,300	68,600	168,280	432,910	192,640
Industrial	109,270	274,540	673,190	1,731,170	770,420
Urban Public Works	47,760	381,300	1,449,000	2,023,800	3,786,000

PAVING BREAKERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	49,920	125,440	307,712	791,424	352,256
Industrial	21,854	54,908	134,638	346,234	154,084
Urban Public Works	-	-	-	-	-

PILE DRIVERS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	95,788	237,358	1,129,149	2,890,800	1,306,569
Nonresidential	49,920	125,440	307,712	791,424	352,256
Industrial	257,565	647,130	1,586,805	4,080,615	1,315,990
Urban Public Works	70,048	552,640	2,125,200	2,968,240	5,552,800

PNEUMATIC TOOLS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	-	-	-	-	-
Nonresidential	5,460	13,720	33,656	86,562	38,528
Industrial	10,927	27,454	67,319	173,117	77,042
Urban Public Works	-	-	-	-	-

ROCK DRILLS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	17,416	43,156	205,118	525,600	237,558
Nonresidential	6,240	15,680	38,464	98,928	44,032
Industrial	24,976	62,752	153,872	395,696	175,096
Urban Public Works	57,312	452,160	1,738,800	2,428,360	4,543,200

ROLLERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	191,576	474,716	2,256,298	5,781,600	2,613,138
Nonresidential	578,420	1,448,440	3,553,112	9,138,474	4,067,456
Industrial	188,881	474,562	1,163,657	2,992,451	1,331,726
Urban Public Works	9,552	75,360	289,800	404,760	757,200

SAWS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	17,416	43,156	205,118	525,600	237,558
Nonresidential	17,160	43,120	105,776	272,052	121,088
Industrial	37,464	94,128	230,308	593,544	264,144
Urban Public Works	28,656	35,298	869,400	1,214,280	2,271,600

SCRAPERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	43,540	107,390	512,795	1,314,000	592,395
Nonresidential	49,920	125,440	307,712	791,424	352,256
Industrial	215,418	541,236	1,327,146	3,412,378	1,518,828
Urban Public Works	22,280	175,840	678,200	944,440	1,766,800

SHOVELS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	43,540	107,890	512,795	1,314,000	593,895
Nonresidential	70,200	176,400	432,720	1,112,940	495,360
Industrial	340,298	354,996	2,096,306	5,391,358	2,399,308
Urban Public Works	120,992	954,560	3,670,800	5,126,960	9,591,200

TRUCKS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	52,248	129,468	615,354	1,576,800	712,674
Nonresidential	64,740	162,680	5,779,215	14,863,932	6,615,808
Industrial	234,150	538,300	1,442,550	3,709,650	1,650,900
Urban Public Works	47,760	381,300	1,449,000	2,023,800	3,786,000

DOZERS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	78,372	194,202	923,031	2,365,200	1,069,011
Nonresidential	64,740	162,680	5,779,216	14,983,932	6,615,308
Industrial	229,467	576,534	1,413,699	3,635,457	1,617,382
Urban Public Works	44,576	351,680	1,352,400	1,888,880	3,533,600

LOADERS

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	609,560	1,510,460	7,179,130	18,396,000	8,314,530
Nonresidential	191,100	480,200	1,177,960	3,029,670	1,348,480
Industrial	37,464	94,128	230,308	148,392	66,048
Urban Public Works	63,680	502,400	1,932,000	2,698,400	5,048,000

CRAWLER TRACTORS, SMALL

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	28,124	64,734	307,677	788,400	356,337
Nonresidential	35,880	90,160	221,168	561,476	253,194
Industrial	6,244	15,688	38,468	98,924	44,024
Urban Public Works	6,368	50,240	193,200	269,840	504,800

CRAWLER TRACTORS, LARGE

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	235,116	582,606	2,769,093	7,095,600	3,207,033
Nonresidential	87,860	170,320	418,196	1,075,342	478,348
Industrial	57,757	145,114	355,829	915,047	407,222
Urban Public Works	70,048	552,640	2,125,200	2,968,240	5,552,300

LOADERS, SMALL

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	60,956	131,046	717,913	1,839,600	831,453
Nonresidential	14,820	37,240	91,352	234,954	104,576
Industrial	10,927	27,454	67,319	173,117	77,042
Urban Public Works	-	-	-	-	-

LOADERS, LARGE

	Large High Density Central	Large Low Density Central	Other SMSA	Urban Fringe	Metropolitan Area Outside Urban Fringe
Residential	661,808	1,639,929	7,794,484	19,972,800	9,027,204
Nonresidential	117,390	294,980	723,604	1,861,083	828,352
Industrial	327,810	823,620	2,019,570	5,193,510	2,311,260
Urban Public Works	187,856	1,482,080	5,699,400	7,960,290	14,891,600

WHEEL TRACTORS

EXHIBIT II-11: NATIONWIDE TOTAL ANNUAL HOURS OF USE OF VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IN DIFFERENT DEMOGRAPHIC CATEGORIES (cont.)

Exhibit II-12 is an arrangement by type of construction of the construction equipment that operate more than five million hours per year in one or more demographic categories. The letter and numbers in the cells indicate the demographic category and the nearest number of millions of hours.

There are 37 entries in the cells, but 11 entries are for equipment named in the background document for tractors and classed as dozers or loaders in the background document for air compressors. Thus of a total of 26 consistent entries, only one represents usage in the central district of a large city. This entry is for air compressors in a large high density central city. Only four of the entries represent usage in smaller cities, "Other SMSA". Twenty-one of the entries are for construction in the urban fringe and in the metropolitan areas outside the urban fringe. Of these 21 there are 7 in nonresidential and 7 in urban public works types of construction projects. Thus the major time of potential exposure seems to be concentrated in nonresidential and public works projects in the outlying areas of cities.

5. Discussion of the Sources of Errors

The assumptions and the data used in this analysis need to be examined. Most of the data used in the background documents were collected in the early 1970's in the Boston area. Toth (op. cit.) has stated that some of them are not representative of current practices nationwide. For comparison, Toth's charts are included as Exhibits II-13 to II-17. His study is confined to construction equipment that is powered by diesel engines. He did not consider onroad trucks. The difficulty of collecting data on current equipment is exemplified by the facts that, despite his sponsorship by the Society of Automotive Engineers and his stature in the industry, only six engine manufacturers furnished data that he requested, and of 48 questionnaires he sent to manufacturers of construction equipment, only 19 were returned, all incomplete. In addition to his survey of manufacturers and a search of the literature, he made field measurements of 90 pieces of equipment of various types and ages (from new up to 15 years) operating on a wide variety of construction projects and sites. For 13 types of construction equipment, which include or overlap many of the types considered in the background documents, he calculated a noise impact rating using the equipment's sound level, the number of machines in use, its usage factor, and the proximity to neighbors of its typical use. Tractors, front end loaders, and backhoes received the highest ratings.

(text continued on page 43)

	Residential	Non Residential	Industrial	Urban Public Works
Air compressor		U6,U15,M7	HD12	
Backhoe			U5	
Concrete Mixer	U8		U6	M8
Concrete Pump				
Concrete Vibrator				
Crane, Derrick				
Crane, Mobile		06,U15,M7		
Generator				U6,M10
Grader				
Paver				
Paving Breaker				
Pile Drive				
Pneumatic Tool				M6
Rock Drill				
Roller				M5
Saw	U5	U9		
Scraper				
Shovel				
Truck			U5	U5,M10
Dozer		06,U15,M7		
Loader		06,U15,M7		
Crawler Tractor, small	07,U18,M8			M5
Crawler Tractor, large				
Loader, small	U7			M6
Loader, large				
Wheel Tractor	08,U20,M9			U8,M15

HD = Large, High Density Central
O = Other SMSA
U = Urban Fringe
M = Metropolitan Area Outside Urban Fringe

Number after letter indicates millions of hours of use

EXHIBIT II-12: DEMOGRAPHIC CATEGORIES AND KINDS OF CONSTRUCTION PROJECTS IN WHICH VARIOUS TYPES OF CONSTRUCTION EQUIPMENT IS USED MORE THAN 4,500,000 HOURS ANNUALLY

Table 6. Original Noise Impact Ranking, Ranked by Sound Level

Equipment Type	Sound Level (dB(A))	Rating Factor*
1. Truck	89	3
2. Scrapers	88.1	3
3. Compressors	86.7	3
4. Front End Loaders	86.5	2
5. Concrete Pumps	86	2
6. Tractors	86	2
7. Cranes	85	2
8. Generators	84	2
9. Pumps	84	2
10. Backhoes	83.7	2
11. Compactors	82.5	1
12. Graders	82	1
13. Pavers	80	1

*Rating Factor #1 80 - 83.5 dB(A)
#2 83.6 - 86.5 dB(A)
#3 86.6 - 89 dB(A)

Trucks category refers to off-highway trucks only.

Tractors category includes tracked vehicles and industrial tractors.

EXHIBIT II-13

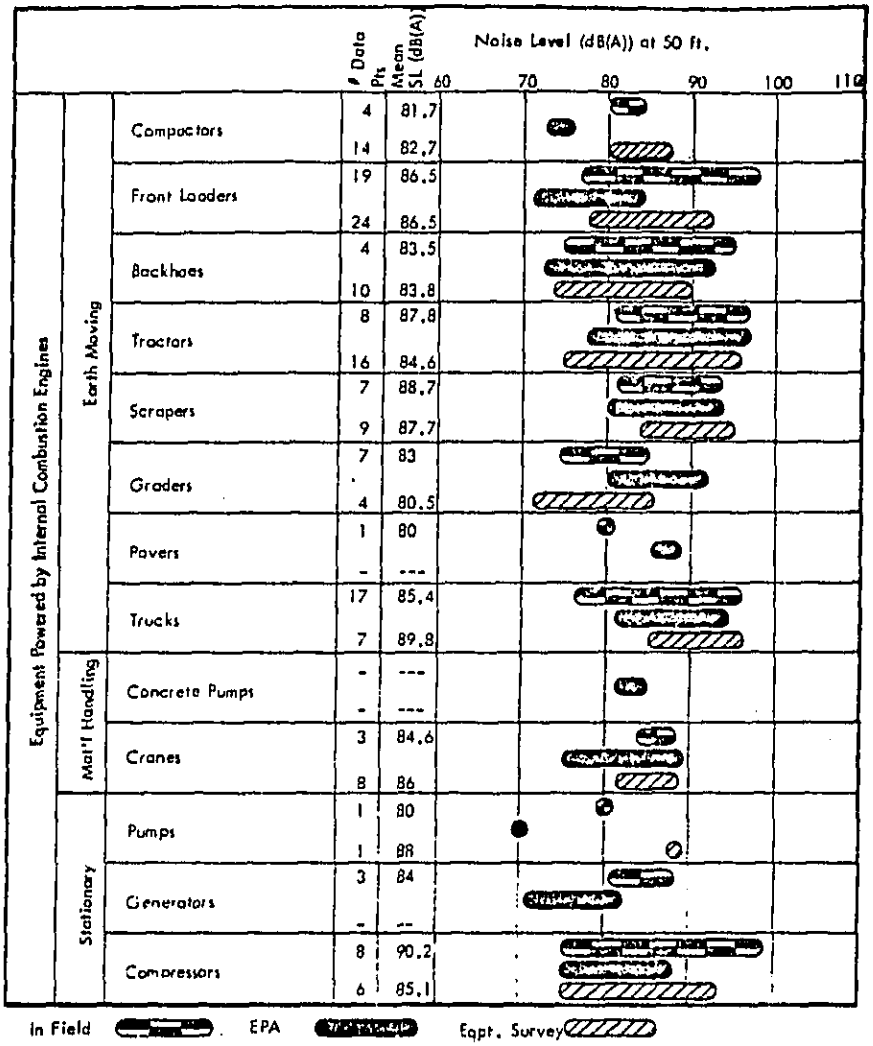


Figure 8. Comparison of Data from EPA Report, Field Survey and Equipment Manufacturer Survey

EXHIBIT II-14

Table 7. Noise Impact Ranking Showing Combined Factors of Work Cycle and Sound Level

Equipment	Work Cycle (%)	Rating Factor*	Combined Rating
1. Trucks	0.60	3	9
2. Scrapers	0.65	3	9
3. Tractors	0.60	3	6
4. Backhoes	0.55	3	6
5. Front End Loaders	0.45	2	4
6. Compressors	0.30	1	3
7. Concrete Pumps	0.30	1	2
8. Cranes	0.35	1	2
9. Generators	0.30	1	2
10. Pumps	0.30	1	2
11. Compactors	0.45	2	2
12. Graders	0.40	2	2
13. Pavers	0.30	1	1

*Rating Factor #3 0.65 - 0.55%
#2 0.50 - 0.40%
#1 0.35 - 0.30%

EXHIBIT II-15

Table 8. Noise Impact Ranking Showing Combined Factors of Work Cycle, Sound Level and Human Population Density Factor

Equipment	Population Density * V. High (5)	High (4)	Med. (3)	Low (2)	V. Low (1)	Combined Rating
1. Backhoe	X					30
2. Tractors		X				24
3. Front End Loaders		X				16
4. Compressors		X				12
5. Truck					X	9
6. Scraper					X	9
7. Concrete Pumps		X				8
8. Cranes			X			6
9. Generators			X			6
10. Compactors			X			6
11. Graders			X			6
12. Pumps				X		4
13. Pavers			X			3

*Population Density is a relative indication of the percentage of time a machine type is used in a highly populated area.

EXHIBIT II-16

Table 9. Final Noise Impact Ranking

Equipment	Machines Produced/Year	Rating Factor*	Combined Rating
1. Tractors	25000	5	120
2. Front End Loaders	15000	4	64
3. Backhoes	3940	1	30
4. Compressors**	5500	2	24
5. Trucks	7970	2	18
6. Compactors	7225	2	12.
7. Cranes	6420	2	12
8. Graders	6000	2	12
9. Scrapers	4600	1	9
10. Pavers	950	1	3

*Rating Factor #1 0 - 4,999
#2 5,000 - 9,999
#3 10,000 - 14,999
#4 15,000 - 19,999
#5 20,000 - 25,000

**Population source for the compressor category was not the Bureau of Census. This figure was based on manufacturer estimates based on size range of 125 cfm or higher.

EXHIBIT II-17

The placement of equipment on the site has been ignored in the background documents and in the analysis of relative potential noise exposure above. If the site is small in area compared to the area in which construction noise has an impact and if the population density is uniform around the site, placement on the site of a particular piece of equipment changes the noise impact of the equipment only slightly. If the area of the site is large, it is possible that a piece of equipment may not be audible at all if it is far from the boundaries and yet may have a major impact if it is located at the edge of the site. This modification can be estimated by consideration of the size of sites in various demographic areas and the utility of the various types of equipment. For example, the average size of construction sites in center cities is smaller than it is in suburban sites and equipment such as air compressors and generators are likely to be placed at the boundaries of the sites so that they are out of the way and can be refueled easily. Backhoes are used to work in close quarters that are typical of concentrated urban excavations, and so forth.

This modification has not been included because it is believed that the errors that result from this simplification are smaller than the errors introduced by the simplification of treating the equipment on a site independently.

This assumption that each piece of equipment at a construction site operates independently of each other equipment is implicit in the calculation of the relative potential noise exposures. If an air compressor and a rock drill are operating together, the sound level of 98 dB at 50 feet from the rock drill will make the 81 dB sound level from the air compressor inaudible at distances greater than the distance between the two machines. For the purposes of noise impact calculations, the air compressor can be ignored. A more common situation is the one in which a loader is working with a truck which hauls away the earth or rubble that the loader scoops up. Typically one truck waits with its engine idling until a previous truck is loaded. Then the truck moves into position and waits, idling, while the loader scoops up material and moves it to the dumping point for as many loads as the truck can take. Then the truck hauls the material away, frequently using full power to do so. Its noise level may dominate the noise level of the loader during the time it moves off the site. Usually the loader works steadily, so both pieces of equipment are in their operating cycle for the times that the truck moves onto and off the site.

The general effect of failure to account for these overlaps in the operating cycles is to overestimate the potential noise impacts of some of the types of equipment, especially the less noisy types and those that are regularly used with equipment that are noisier than they are. Estimation and removal of these errors will not affect significantly the conclusions about the noisiest pieces of equipment and may have only small affects on the moderately noisy equipment that is very widely used. More detailed estimates of these errors have not been calculated, but the methods have been developed and are described in the next section.

6. Methods for Estimating the Errors Introduced by Treating the Different Pieces of Equipment Independently

The effects of more than one piece of construction equipment's operating simultaneously can be estimated more easily if four different situations are separated.

1. The use of one piece of equipment is substantially unrelated to the use of another. For example, the use of an electric saw is not closely related to the use of an air compressor and neither is closely related to the use of a truck or a loader. Under these circumstances one may fairly assume that the sound levels of the equipment will be combined at random times. Thus, if one piece of equipment is operated 0.3 of the time and another is operated 0.2 of the time, then 0.06 of the time both will be operating and their combined noise level can be calculated for that portion of the construction phase and type to which those duty cycles apply.

2. The use of one piece of equipment is closely dependent upon the use of another. For example, a paving breaker, a pneumatic tool, or a rock drill is used only when an air compressor is in use, too. A concrete pump or a concrete vibrator is used only when a concrete mixer also is used. An asphalt paver is used only when a roller also is used (but only an unstated fraction of the pavers are asphalt pavers.) A pile driver is always used with a mobile crane or a derrick or both, (the pile driver is so much noisier than either, that it matters little which one is used). Under these circumstances, it can be assumed that the dependent equipment's use cycle lies within the cycle of the independent equipment. If the air compressor is used 0.3 of the time and pneumatic tool is used 0.2 of the time, then 0.1 of the time the air compressor will be in operation alone and 0.2 of the time both equipments will be operating. The impact of the combined noise levels can be calculated accordingly.

3. The use of one piece of equipment effectively precludes the use of another. For a particular part or location of a project use of the three groups of equipment, earthmoving (backhoe, dozer, loader, shovel), paving (paver, roller, concrete mixer, concrete pump, concrete vibrator), and breaking tools (paving breaker, pneumatic tool) are mutually exclusive. Under these circumstances it is fair to assume that the two pieces of equipment from different groups do not overlap in their cycles and that the impacts of their noise levels are independent and should be added.

4. One piece of equipment may be substituted for another. For example, during the excavation phase, backhoes, dozers, loaders, and shovels may substitute for one another in many projects, even those of the same broad type. The operational usage cycles that appear in the tables for the same phase and type of construction are representative of many sites and not typical of one. For example, a usage cycle of 0.2 for a backhoe and of 0.2 for a dozer really may indicate a usage of 0.4 for either on half of the projects as readily as it indicates that both are used 0.2 of the time on the same projects. Under such circumstances it is unwise to make any assumptions about the degree of overlap of their cycles, and it is safer to treat them as independent sources.

Rules for calculating the effects of the noise from one piece of equipment on the effective noise level of another are as follows:

1. If two pieces of equipment have average noise levels that differ by 7 dB or more, disregard the one with the lower noise level when both are operating. (The contribution of the less noisy one will be a half a decibel or less to the combined noise level.)

2. When two or more pieces of equipment are operating simultaneously, and when their average noise levels are within 7 dB of one another, calculate their combined noise levels by adding their acoustical powers and converting the sum to decibels. Allocate the higher noise levels to the equipment during the period they are used simultaneously according to the ratio of their independent noise levels relative to a chosen threshold.

Exhibit II-18 shows, for each phase of each type of construction, the types of equipment that have usage factors equal to or greater than 0.1. They are plotted against a scale of average noise levels to show clearly those that may be disegarded by the use of rule 1 above and to permit easy grouping of the substitutional, independent, and dependent categories.

As an example of the sort of calculation that is required to account for overlapping duty cycles, consider the use of a concrete mixer which produces a noise level of 85 dB at 50 feet and a mobile crane which produces a noise level of 83 dB at 50 feet. Suppose they are working at a site in an area with a population density of 10,000 people per square mile. When the crane is used to lift reinforcing bars into place in concrete forms, it works by itself. When the forms are low and the mixer can deliver concrete into wheel barrows, it works by itself. When the mixer delivers concrete into a bucket that the crane lifts to the top of the forms, both work at the same time. Each hour the mixer operates alone, it creates a relative potential noise exposure of 85-75=10 times the population density, or 100,000. Each hour the crane operates alone, it creates a relative potential noise exposure of 83-75=8 times the population density, or 80,000. Their combined noise level is 87 dB, so each hour that they work together they create a relative potential noise exposure of 87-75=12 times the population density, or 120,000. Thus two equipment-hours of independent operation causes 50 percent more relative potential noise exposure than two equipment-hours of concurrent operation.

Note that this ratio depends upon the threshold of noise levels. If a number different from 75 dB were used, the ratio will be different. If a high enough threshold is used, the relative potential noise exposure might be higher for the combined operation than it is for the separate operations. For example, if the threshold were set at 83 dB, the relative potential noise exposure would be twice as high for an hour of combined operations as it is for an hour of operation of both pieces of equipment alone.

In the example given earlier, however, the saving of 60,000 units of relative potential noise exposure should be distributed to the two types of equipment according to the ratio of their noise levels relative to the threshold. Because the hours of overlap are different for each phase of each kind of construction and the population densities are different for each kind of construction, the calculations of the compensations for overlapping duty cycles will be lengthy.

(text continued on page 51)

NOISE LEVELS OF EQUIPMENT USED 10% OR MORE OF THE TIME
Domestic Housing

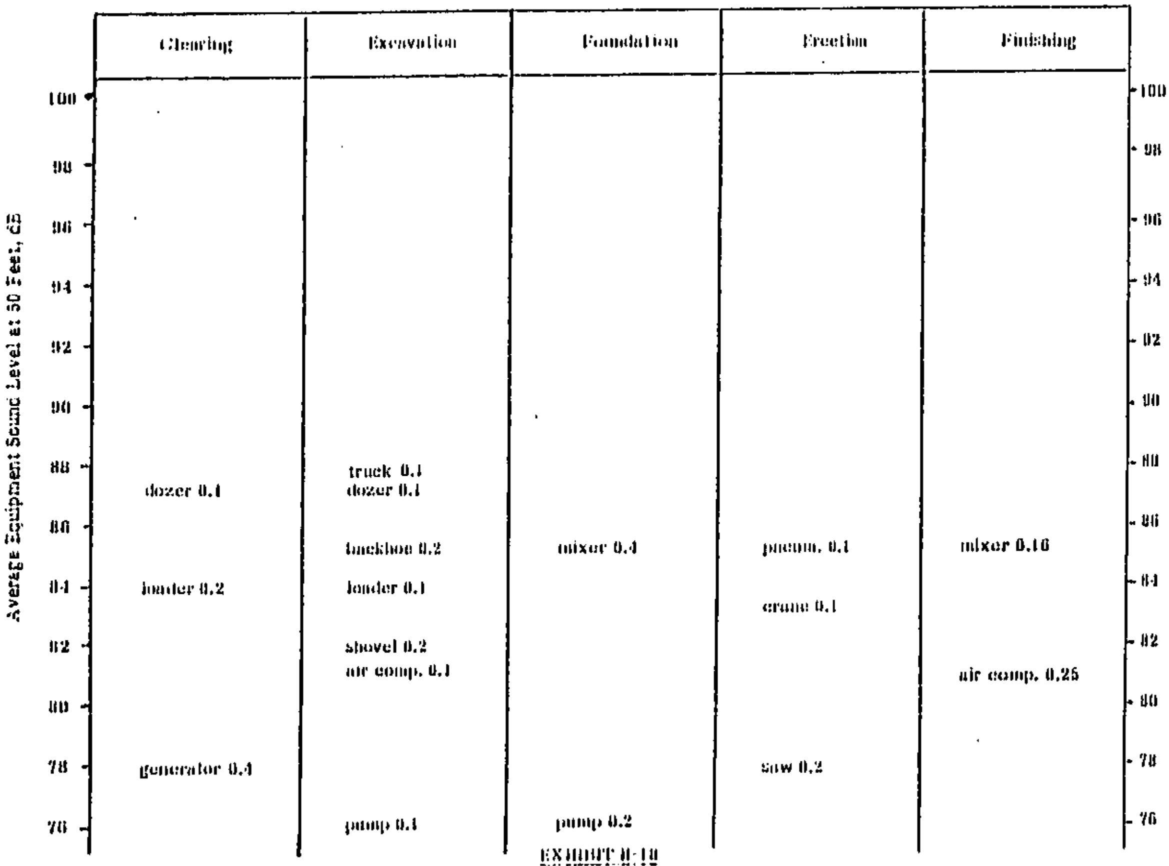


EXHIBIT II-10

Nonresidential Construction

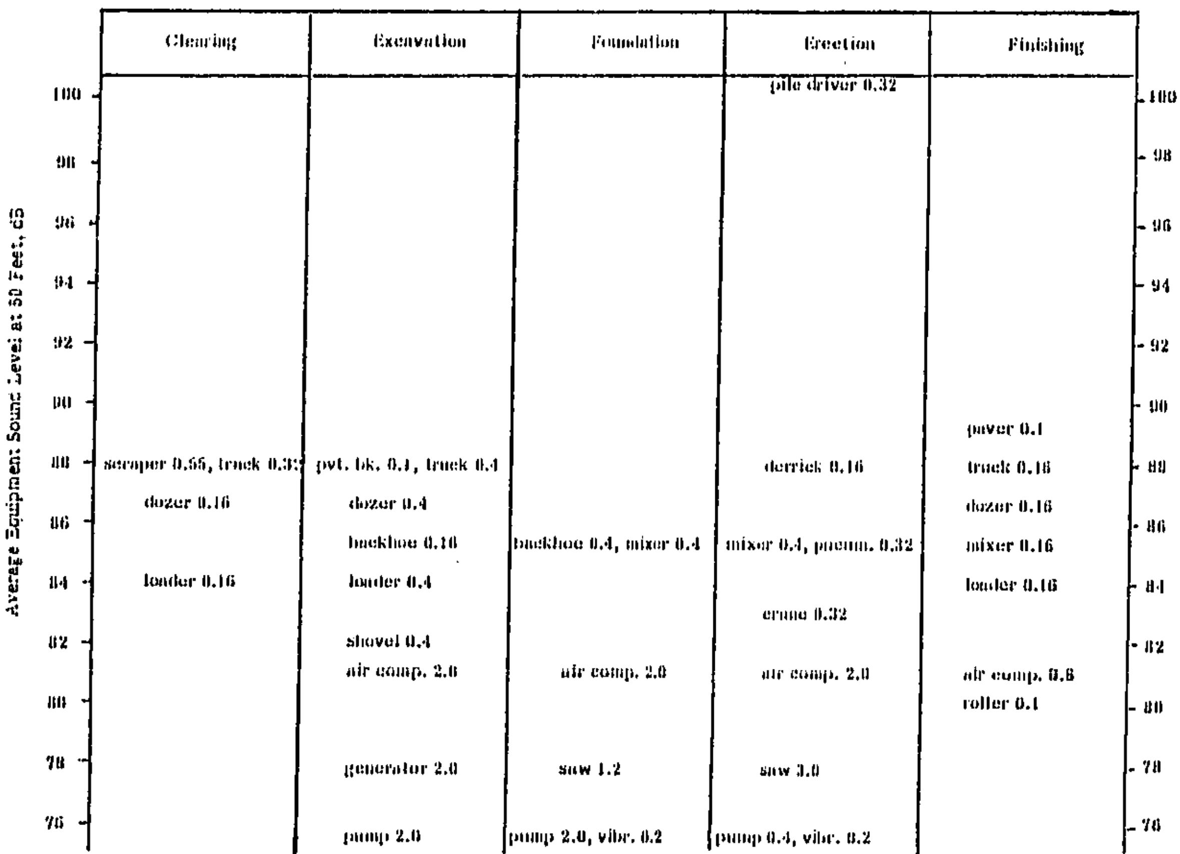


EXHIBIT II-18 (Cont.)

Industrial Construction

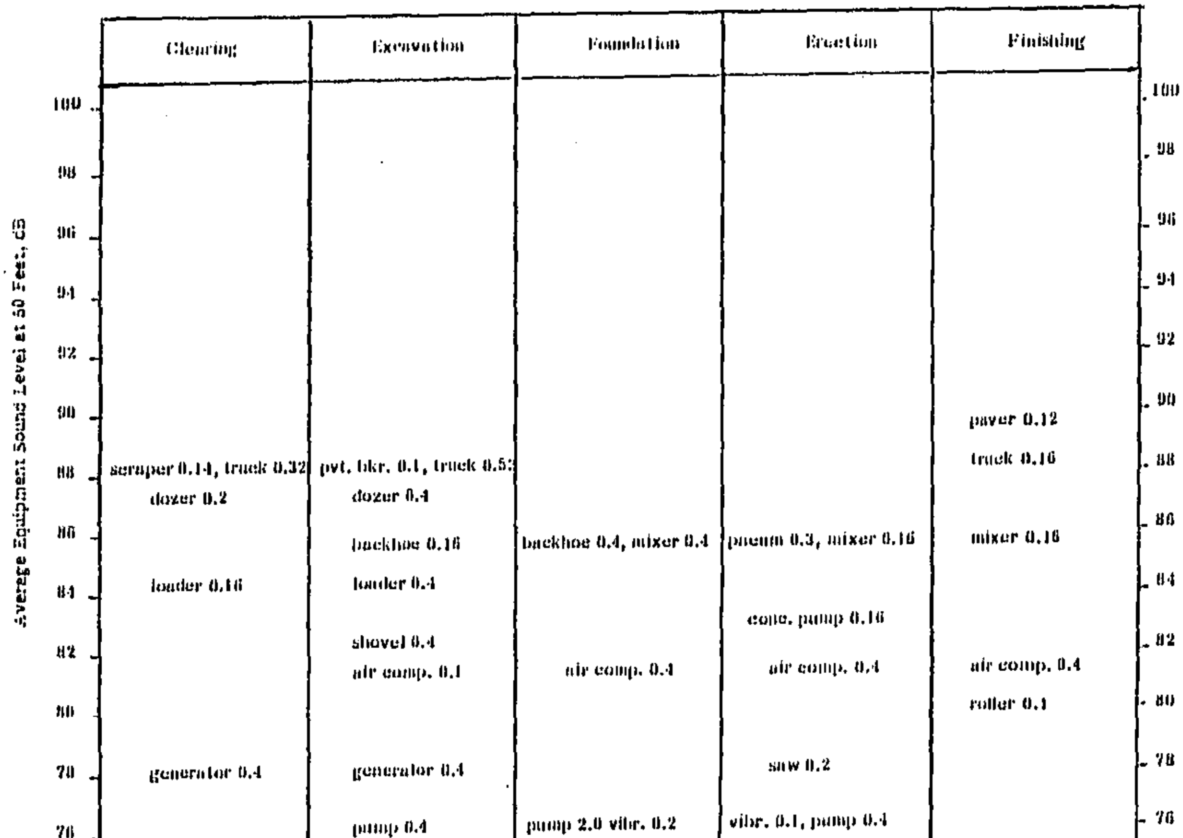


EXHIBIT B-8 (Cont.)

Public Works Construction

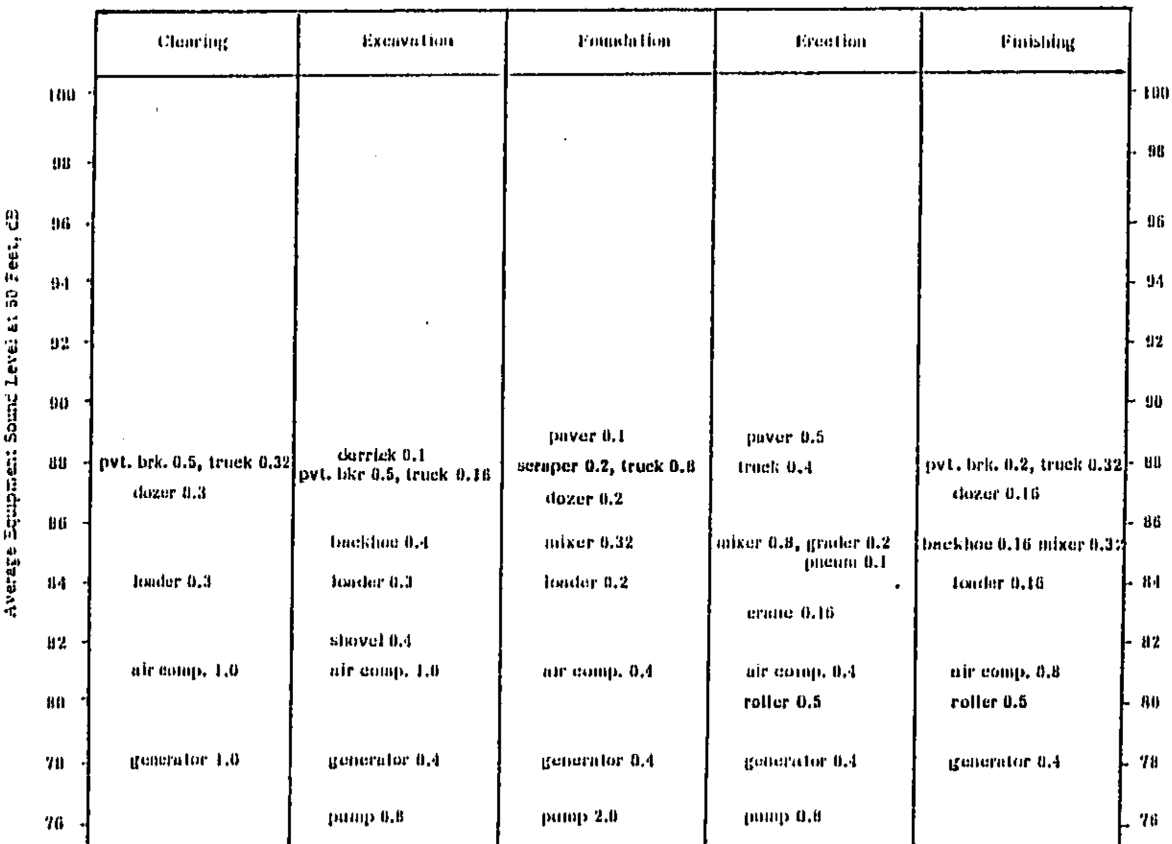
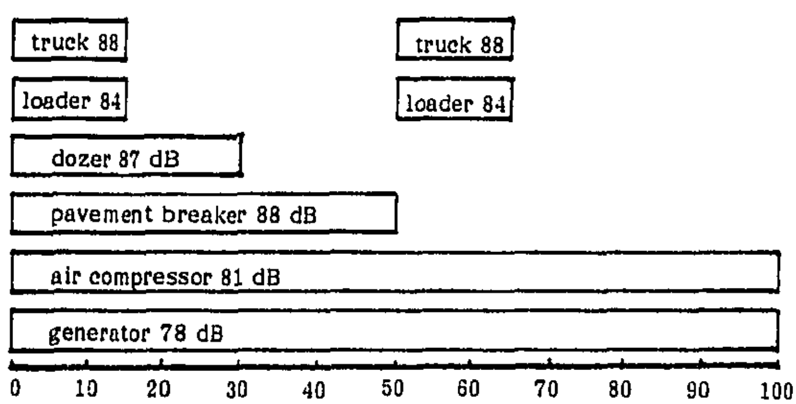


EXHIBIT II-8 (Cont.)

These tables and rules also can be used to calculate the benefits in particular circumstances of changes in the noise levels of particular pieces of equipment. As an illustrative and fairly complex example, consider the clearing phase of a public works construction project. Exhibit II-18 shows that an air compressor and a generator are used full time and that a pavement breaker is used half the time. A dozer, a loader, and a truck each are used 30 percent of the time (rounding the usage of the truck from 0.32), but they are not all used together all the time. Typical usage is for the dozer to work with and around the pavement breaker and for the loader to put the broken rubble into the truck. Assume that the dozer works only when the pavement breaker is working and that half the time that the loader and truck are used the dozer also is operating. Part of the time the loader fills the truck when the dozer and the pavement breaker are not working. The timing overlaps are shown in the chart below.



Percentage of Construction Time Equipment Used

Note that there are five conditions (where the symbol $\oplus$ means "combined with" or "the energy sum").

1.	truck+loader+dozer+breaker+compressor+generator	-15% of the time
	88 $\oplus$ 84 $\oplus$ 87 $\oplus$ 88 $\oplus$ 81 $\oplus$ 78 $\oplus$	= 93.4 dB
2.	dozer+breaker+compressor+generator	- 15% of the time
	87 $\oplus$ 88 $\oplus$ 81 $\oplus$ 78	= 91.1 dB
3.	breaker+compressor+generator	- 20% of the time
	88 $\oplus$ 81 $\oplus$ 78	= 89.1 dB
4.	truck+loader+compressor+generator	- 15% of the time
	88 $\oplus$ 84 $\oplus$ 81 $\oplus$ 78	= 90.3 dB
5.	compressor+generator	- 35% of the time
	81 $\oplus$ 78	= 82.8 dB

The energy equivalent average level of all conditions is 89.6 dB. If the noise levels of the dozer, loader, and pavement breaker are reduced by 3 dB each, a similar calculation yields an energy equivalent average level of 88.3 dB.

A simpler example of the same sort is the excavation phase of a residential construction project. Exhibit II-18 shows that a truck, a dozer, a loader, an air compressor, and a pump each are used 0.1 of the time and a backhoe and a shovel each are used 0.2 of the time. The worst case is when all of the equipment is used at the same time. Acting together they will produce a total noise level of 93.1 dB, but only for 0.1 of the time. The bacckhoe and the shovel together can produce a total noise level of 86.8 dB for another 0.1 of the time. The energy equivalent average level of all conditions (including no sources 0.8 of the time) is 84.0 dB.

If the dozer and the loader each have their noise levels reduced by 3 dB, the result is that the noise level from all the equipment operating together is 92.2 dB for 0.1 of the time. The noise level from the backhoe and the shovel operating together is not changed, and the energy equivalent average level becomes 83.3 dB as a result of quieting the two pieces of construction equipment.

III. NOISE CONTROL MEASURES AVAILABLE

A very wide variety of measures is available to control and to abate construction noise. They range from simply limiting the hours of operation of particular kinds of equipment such as pile drivers to requiring redesign of all equipment that is sold in interstate commerce in the country. For ease of discussion and comparison the measures can be categorized as follows:

In-use controls
Path controls
Produce and noise control information
Design changes and retrofitting
Financial incentives

The implementing and enforcing organizations for each measure are indicated in the discussions that follow.

A. IN-USE CONTROLS

These are controls on the operation of equipment that already exists. They may be used by themselves, or they may be combined with noise level regulations. Property line regulations limit the noise level that construction activity can produce at the boundary of an abutting property. The limit may be different for different hours of the day or days of the week. Source-distance regulations limit the use of equipment that produces noise that exceeds a defined level at a defined sitance. Most local noise level regulations which are applicable to construction equipment are property line regulations and are enforced by the police, the building department, or the environmental department.

1. Hours of Operation

A local regulation, often included in the building permit, may require that construction operations or the operation of a particular kind of equipment such as jackhammers, pile drivers, or riveters, be confined to particular hours of the day and days of the week. This control is easy to state, easy to enforce, and easy to understand. The police, building or health department may enforce it. It may increase construction costs by extending the duration of the project and may not change the noise exposure or impact at all. It may merely redistribute the time in which the exposure and impact occurs.

2. Operation With Noise Control Equipment

A local regulation may require all construction equipment to be operated with all the manufacturer's noise control equipment in place and in good repair. (Toth found that, out of 90 pieces of equipment that he surveyed in the field, 34 were being operated without any mufflers at all.) This rule requires the operator to use the muffler, acoustical enclosures and hoods, and other noise control devices that the manufacturer originally included in the equipment. This rule is easy to enforce, usually by inspection, and is effective in preventing the contractor from removing the muffler or operating an air compressor with the enclosure doors open, for example. Either of these two changes easily can reduce noise levels of specific pieces of equipment by 10 dB. The police, building, or health departments may enforce the regulation.

3. Maintenance

A local regulation may require all construction equipment to be maintained so that its noise emissions are not significantly greater than those of new equipment. This regulation is aimed at replacement of rusted out enclosures, loose chain drives, loose tracks, worn bearings, defective fans, worn pump rotors, and other equipment that causes unnecessary noise. It complements the regulation requiring maintenance of the noise reduction equipment, but is more difficult to enforce because the sources of the noise are not so obvious. The building department usually is best qualified to enforce the regulation.

4. Location of Equipment at the Site

A local rule may require certain equipment such as air compressors or concrete mixers on urban sites to be located on the side of the site farthest from residences as an example. These controls must be balanced with other requirements such as those for safety, drainage, access of emergency vehicles, non-interference with traffic, and access to utilities. This kind of restriction does not permit the contractor to use discretion about the use of quieter equipment. An alternative is a local ordinance that limits noise levels at a property line; this gives the contractor the opportunity to trade off quieter equipment for more flexibility in its placement on the site. The police or building department usually is best qualified to enforce these limits.

5. Use of Alternate Equipment

A local regulation may limit the types of equipment that can be used in urban or suburban construction projects. This rule may prohibit, for example, riveted steel construction or any pile drivers except hydraulic or pneumatic cushion drivers. In some cases the regulation may be written as a limit on the noise level at a particular distance from the equipment when it is operating. This sort of regulation can be enforced by the building department when it approves the equipment that will be used on the construction site.

6. Rerouting Vehicles

A local regulation may require that the route used by materials handling equipment and construction vehicles be approved by the police or the environmental department when the building permit is issued. This kind of regulation can keep trucks and other noisy vehicles off the residential feeder streets during the construction project. Police officers are best qualified to enforce the regulation.

7. Operator Concern for Noise During Construction

As noted in Section I, most of the construction workers are not residents of the neighborhoods in which the construction site is located. They have little affinity for the neighborhood and will not expect to work there very long. Any measure that will increase their sensitivity to the needs of the residents for quiet will be helpful. If the contractor and the workers are aware of an active and assertive program for community noise abatement and control, noise control measures may be designed in the planning of the project. When the project begins, adults and children from the neighborhood may get cooperation and consideration from the operators of construction equipment by identifying the houses that contain invalids, children that take naps, and night shift workers who sleep in the daytime.

B. PATH CONTROLS

These regulations and practices are aimed at reducing the noise that reaches residents by interfering or lengthening the path by which the noise reaches the hearers.

1. Barriers and Berms

At some construction sites local regulation may require extra earth to be used as a berm between the construction activity and the residents. After the construction is completed it may be hauled away or it may remain as a barrier against highway noise, for example. At other sites it may be advisable to erect precast concrete slab barriers to reduce the noise that reaches residents. These slabs can be reused many times for different projects. Because of the penetrations that are necessary to allow access for delivery of men and materials, the barriers will not often achieve the 10 dB of noise reduction that is expected from highway barriers. Building inspectors can enforce the terms of the building permits.

2. Shielding

Local regulations and building permits may require contractors to do all the shielding they can. Frequently construction sites receive large stocks of materials before they are needed. These stocks can sometimes be used to form shields or barriers until they are needed. If they can be piled tightly along an exposed side of a site, they can offer considerable noise reduction, especially if the work is below grade. Light weight or openwork materials will provide little acoustical shielding. Building inspectors can inspect to see if the contractor is making a best effort.

3. Enclosures for Equipment and Sites

Local regulations and building permits may require enclosures where this is feasible. Enclosing a particular, fixed piece of equipment such as generator, a pump, or an air compressor is an effective way of reducing its noise, particularly if the geometry of the site requires this piece of equipment to be near residences. Access for maintenance and connections needs to be provided, but enclosure on the top and three sides, preferably with an absorbent, lined shield, can provide significant noise reduction.

In some cases, such as tunneling and subway construction, it is possible to enclose the site entirely except for access for materials and workers and some fans, air compressors, and pumps that require outside venting. Roofing over a site can be of value if the neighboring residences are apartments close to and above the construction work. These requirements for enclosing the work and the equipment may be included in the terms of the building permit and enforced by the building inspector.

4. Land Use Controls

In rare cases local regulations may prevent construction of residences or their occupancy until especially noisy construction in their neighborhood is completed. This noise control measure is available in the case of major highway projects or bridges or subways. In this way it may be possible to limit any increase in the number of people who are impacted by the construction. Zoning and building departments can enforce such regulations.

C. PRODUCT AND NOISE CONTROL INFORMATION

Providing State and local officials, public interest groups, construction constractors, and consulting design engineers with information concerning the noise problems and the alternative solutions is a nonregulatory method of encouraging voluntary noise reduction. Organizations such as the National League of Cities, the National Association of Counties, and the National Association of Neighborhoods have volunteered to assist in publicizing noise control information. One of the most frequent causes of high levels of construction noise is that little is known about the sources of the noise and their effects, and it is thought that nothing can be done. Frequently contractors are not aware that quiet models of equipment are available, or they think that the possible higher cost is not justified because there is no need for lower noise levels. Engineers sometimes are unaware that quieter alternative equipment can be used if it is specified. Pile drivers offer an excellent example. Although all structural engineers know that bolting or welding is a quiet alternative to riveting structural steel, they may not know that vibratory hydraulic and pneumatic cushion pile drivers are quiet alternatives to steel impact drivers.

Local officials and citizens' groups similarly often are unaware of the noise control measures, voluntary and regulatory, that are available to them if they find construction noise objectionable. Citizens Against Noise has pioneered in providing such information. The National Association of Noise Control Officials represents almost all the communities and States that have effective noise control programs in the nation, but does not reach the communities that do not know that such an organization exists.

Highly visible, key construction projects such as the Pennsylvania Avenue Redevelopment Area in Washington, D.C. offer excellent possibilities for demonstration programs.

D. DESIGN CHANGES AND RETROFFITING

1. New Product Regulations

The U.S. Environmental Protection Agency is required by the Noise Control Act of 1972 to issue noise emission regulations for any product identified as a major noise source if standards are feasible. The EPA has issued noise emission standards for two products used in construction work, portable air compressors and highway trucks. Equipment classed as wheel and crawler tractors used in construction and that classed as pavement breakers and rock drills have been identified by EPA as major noise sources and proposed noise standards for tractors have been drafted but not promulgated.

Regulations of this sort have the advantages that they apply to all new equipment of that type sold in the U.S., the responsibility for compliance and reporting is the manufacturers', and enforcement is by Federal employees. The regulations have the disadvantage that they do not apply to existing construction equipment, which frequently has an average life of 15-30 years in service, nor do they apply to new equipment after it is sold. They apply only to equipment that has been identified as a major source of noise and this means a significant national impact on populations. Local conditions may be such that a particular piece of equipment is a major source of noise, but if its incidence in the nation as a whole is low, State or local regulations will have to deal with it.

2. New Accessory Part Regulations

EPA can issue new product regulations on aftermarket products such as exhaust and induction, mufflers and enclosures for pneumatic tools. It has done so only in the case of motorcyle exhaust systems. No aftermarket products in the construction industry have been regulated in this way. The EPA regulations of this sort have the same advantages and disadvantages that the regulations for new equipment have.

3. Retrofit Modifications and Kits

The muffler industry in the U.S. has done a lot of research and investigation into their ability to reduce noise in existing equipment through retrofitting better, more effective mufflers. Manufacturers of construction equipment and aftermarket equipment manufacturers can make available retrofit kits and can recommend changes to reduce noise. Users must decide whether to buy and install the noise control equipment. In part they will be motivated to do so if the information about the equipment's existence and efficacy is known by them, by local officials, and by citizens' groups.

4. Maintenance and Operations Innovations

If techniques are developed for maintaining and operating specific pieces of equipment so as to reduce noise levels, they can be used by operators and contractors of construction equipment if they are sufficiently informed and motivated. Unless the techniques save money, they will be adopted only if local officials and citizens' groups exert pressure for them.

E. FINANCIAL INCENTIVES

1. Penalties for Operation of Noisy Equipment

Contractors may be penalized for operating noisy equipment by charging more for a building permit if the plans show the use of equipment which is known to produce sound levels at a stated distance which are in excess of the limits in a regulation. Alternatively, the requirement may be for a higher performance bond if such equipment is to be used, on the grounds that an injuction against the use of such equipment is more likely and that, therefore, the contractor is more likely to fail to finish the work satisfactorily. As a third alternative, the community may tax construction projects on the basis of their duration and may limit hours of construction more severely if noisy equipment is used. These measures may be carried out by the building department with the cooperation of the police. They will not be effective in limiting noise from public works performed by municipal employees.

2. Higher Prices for Quiet Public Works Operations

Many municipalities and States contract for public works construction, improvements, and repairs. The contracts may permit higher prices to be paid if the work will be done with equipment or techniques that will produce lower noise levels as measured by municipal employees during construction activity. The public works department will be responsible for such a program.

3. Greater Requirements for Documentation of Noise Impacts

If the noise levels from a project will exceed a threshold, contractors may be required to submit noise impact assessments before a building permit is issued. Avoidance of this documentation is an incentive to plan for quiet operations. Even if the documentation is required, the contractor will know that a noisier project will receive more attention and questions during the planning and execution stages than a quieter project will. Both the building and the public works departments can be involved in this incentive. Exhibit III-1 shows a comparison of the features of the various controls.

	Effectiveness in reducing noise exposure	Speed with which effectiveness is obtained	Relative over-all cost to construction contractor	Place of responsibility primary
A. In-Use Controls				
Hours of operation	medium	very fast	medium	local
use of noise control equipment	high	fast	medium	State & local
maintenance	medium	fast	medium	local
equipment location at the site	medium	fast	low	local
use of alternate equipment	medium	fast	medium	local
rerouting vehicles	medium	very fast	medium	local
operator concern	high	fast	low	private sector
B. Path Control				
barriers and berms	low	fast	medium	State & local
shielding	low	fast	medium	State & local
enclosures	medium	fast	medium	State & local
land use controls	low	fast	medium	local
C. Product Information	medium	slow	medium	private sector
D. Design Changes and Retrofitting				
new product regulations	medium	slow	high	Federal, State & local
accessory regulations	medium	slow	high	Federal State & local
retrofit modifications	medium	medium	high	Federal State & local
innovation	medium	slow	high	private sector
E. Financial Incentives				
penalties for noisy operation	medium	medium	medium	local
higher prices for quiet operations	medium	medium	none	State & local
greater documentation requirements	medium	medium	low	local

EXHIBIT III-1: FEATURES OF THE CONTROLS

IV. NATIONAL STRATEGY

A. CONTROL OPTIONS

Construction noise exposure, as discussed in Section II, can be reduced by exercising various controls which are outlined in Section III. Since the EPA construction noise model is not perfected to the point where it can be used to simulate the effectiveness of individual and combinations of controls, the probable effectiveness is stated in broader terms. In order to make clear the impact on the construction industry of the various possible controls, the analysis described in the previous section has kept separate the following pertinent characteristics:

1. Geographic characteristics of construction sites (ranging from remote, large area sites to urban, concentrated sites)
2. Phases of construction activity (ranging from demolition clearing to finishing and cleanup)
3. Construction techniques and equipment associated with the techniques (ranging from housebuilding to digging canals)
4. Exposure from construction noise

The conclusion is that several controls have significant payoffs in terms of reducing noise exposure, and that different controls are effective in different sectors of the construction industry. Each of the viable control options which are listed below has several distinct advantages and disadvantages, but they all share the advantage that the incidence of their costs is on the products or users of the construction.

OPTION 1: In-use controls, such as

(a) limiting hours of noisy construction project operations,
(b) requiring that all construction equipment be operated with original noise control equipment in place and in good repair, and
(c) setting not-to-exceed limits on noise levels at the property line.

Advantages

- Immediately effective
- Large reductions in annoyance in most cases
- Large reductions in noise level in some cases
- State or local control with no preemption by Federal action
- Applies to all equipment operated singly and jointly
- Possible variations to suit local conditions
- Possible fuel conservation

Disadvantages

- Uniform effectiveness cannot be assured nationwide
- May not be sufficiently effective in inducing new designs of quieter equipment.

OPTION 2: Financial incentives, such as

(a) higher building permit fees and more documentation if noisier equipment is to be used,
(b) committment to a buy-quiet program,
(c) quiet equipment and operations required as a condition for government contracts and assistance, and
(d) size of performance bond made a function of predicted noise emissions.

Advantages

- Quickly effective
- Significant, permanent noise reductions if quiet equipment is bought
- State or, particularly, local control with no preemption by Federal action
- Applies to all equipment operated singly or jointly
- Possible variations to suit local conditions
- Relatively low cost
- Provides incentives for new design of quieter equipment

Disadvantages

- Uniform effectiveness cannot be assured nationwide
- Requires widespread information regarding quiet equipment
- Less obvious to the general public as an effective, direct control

OPTION 3: Path controls, such as

(a) barriers and berms during construction and
(b) stacks of building materials.

Advantages

- Quick and relatively certain noise reductions during initial phases of construction projects
- Relatively inexpensive, especially if safety barriers already are required
- Local control without preemption by Federal action
- Applicable to all sources of noise including nonequipment noise
- Possible variations to suit local conditions

Disadvantages

- Uniform effectiveness cannot be assured nationwide
- Not effective during all phases of construction
- Not effective on all construction projects
- Little incentive for new design of quieter equipment

OPTION 4: Information campaigns, such as

(a) organized diffusion of publicity about quiet equipment and techniques to contractors and design engineers,
(b) demonstration projects for State and local governments and members of construction industry trade associations, and
(c) public information campaigns and participatory conferences for citizens' groups in which noise controls and quiet equipment are featured.

Advantages

- Significant permanent noise reductions if quiet equipment is bought
- Possible variations to suit local conditions
- Provides incentive for new design of quieter equipment
- Voluntary instead of obligatory
- Applicable to many noise sources and activities

Disadvantages

- Effective only slowly
- Likely highly variable in success
- Continuous effort required
- Must compete with many other information campaigns

OPTION 5: New EPA medium and heavy truck regulation, with noise level limits lower than current limits and with applicability to concrete mixers and other over-the-road construction trucks.

Advantages

- Very effective in reducing projected noise exposure
- Applies to the most commonly used single piece of equipment for all construction projects
- Uniform effectiveness nationwide

Disadvantages

- Requires enforcement (State and local) after sale
- Enforcement of aftermarket equipment is required, especially for frequently damaged exhaust systems
- Effective only slowly as new equipment enters fleet
- Federal preemption of State and local controls
- Relatively high cost new designs required
- Does not apply to discretionary operational use

OPTION 6: New EPA wheel and crawler tractor regulation applying to dozers, loaders, and some backhoes.

Advantages

- Reductions of noise from one of the major contributors to construction noise during some phases of construction
- Provides encouragement for new designs of other quiet equipment
- Uniform effectiveness nationwide
- Contributes to conservation of hearing of operators

Disadvantages

- Can be overshadowed by noisier pieces of equipment
- Requires enforcement (State and local) after sale
- Enforcement of aftermarket equipment is required, especially for frequently damaged exhaust sytems
- Effective only slowly as new equipment enters the fleet
- Federal preemption of State and local controls
- High cost new designs required
- Net negative implications for international trade
- Does not apply to discretionary operational use

OPTION 7: New EPA rock drill and pavement breaker regulation

Advantages

- Reductions of noise from one major contributor during some phases of construction
- Provides encouragement for new designs of other quiet equipment
- Uniform effectiveness nationwide
- Contributes to conservation of hearing of operators

Disadvantages

- Can be overshadowed by noisier pieces of equipment
- Requires enforcement (State and local) after sale

- Enforcement of after market equipment is required, especially for exhaust systems
- Effective only slowly as new equipment enters use inventory
- Federal preemption of State and local controls
- High cost new designs required
- Net negative implications for international trade
- Does not apply to discretionary operational use

OPTION 8: New EPA requirement for labeling of construction equipment, such as,

(a) back up signals on all mobile equipment,
(b) earthmoving equipment,
(c) rock drills and pavement breakers,
(d) pile drivers,
(e) fixed cranes and derricks, and
(f) mobile cranes.

Advantages

- Can be made applicable more quickly than regulations limiting noise levels
- Provides incentives for new designs for quiet equipment
- Supports buy-quiet programs and financial incentives, especially for State and local governments with large numbers of public works projects
- No Federal preemption of State and local controls
- May permit measurement of after-sale deterioration in use and changes in noise levels of new equipment as it is introduced.
- Uniform nationwide standard for all manufactures
- Relatively inexpensive

Disadvantages

- No certainty of noise level reductions
- Effective only slowly as the equipment enters the inventory
- Does not apply to discretionary operational use

B. SUGGESTED OPTIONS

Construction noise is a site-specific problem. As Sections I and II delineate, there are many factors which contribute to construction noise, including the type or phase of construction, the combination of equipment used, the site layout, and the techniques being used.

There is no blanket prescription for controlling construction noise and the exposure to the noise. Similar types of construction activity can have different exposure impacts, depending on the location of the construction and the population surrounding the site.

The uniqueness of each construction site calls for a combination of control measures centered around those measures which can be directed specifically to the type of site and the resultant exposure. For the most part, this is best done at the local level, where all factors can be considered, ordinances can be enforced, and, if necessary, penalities can be levied. The primary thrust of construction noise control, therefore, must revolve around in-use controls. A few other types of noise controls can be used to supplement in-use controls; these will be discussed later.

In-use controls include hours of operation, operation of equipment with noise control equipment, location of the equipment on the site, use of alternate equipment, rerouting vehicles, property-line standards, and operator concern. For more detail on these controls, see Section III.

In-use controls have many advantages over other types of controls. They can be effective immediately after a local ordinance is passed, whereas a new product regulation takes many years to be reflected in the fleet. In addition, the noise from a piece of equipment which has been regulated may be overshadowed when used in conjunction with another piece of equipment with an equal or higher noise level. Also, the regulated equipment is not likely to be used during all construction phases. Therefore, the total noise from the site may not be lessened significantly. (See the discussion on noise impact calculations in Section II).

Adverse effects from noise are caused not only by the level of noise, but also by the time of day or night in which the noise is made. For example, a noisy operation in a commercial area are best done after regular working hours, when most workers are at home. Conversely, noisy operations in a residential area are best performed during the day, when most people are not sleeping and many are not at home. Although the overall level of noise from the site may not be mitigated, exposure to the noise can be greatly reduced.

Large reductions in noise levels (and exposure) can be achieved by the operation of construction equipment with its proper noise control equipment in place and in good repair. As cited earlier, for example, just correcting a defective muffler can reduce the noise by 10 dB. Since Toth found that 38 percent of all equipment inspected had no mufflers, correcting this one problem can offer substantial relief.

Operator concern can greatly affect the way equipment is used and maintained. This has to be done through information dissemination and training. A side benefit is the possible fuel conservation which may occur through proper use and maintenance of equipment. For example, chances are that a truck in good repair with a proper exhaust system and a temperature-actuated fan will be more efficient than a truck with improper back pressure resulting from a defective exhaust system and a direct-drive fan.

These types of in-use controls apply to all types of equipment — whatever the combination. Unlike most new product regulations, they are not dependent on technological (and cost) considerations.

Another important factor is that Federal preemption is not involved with these types of controls. New source regulations may be, in effect, "capping" regulations or of minimal value due to technology constraints. That means that while the noise level of a regulated piece of equipment would be kept below a certain level, chances are that that level would not be set low enough to cause real innovation in reducing noise levels. New product regulations may set an average level, and would, therefore, condone the status quo for some equipment, lower the levels for other equipment, and permit the escalation of noise from still other equipment. Meanwhile, these regulations would prohibit any States or localities from imposing stricter standards. In-use controls, on the other hand, can be as strict as any locality wishes. A noise sensitive community has many tools at hand to control construction noise. These in-use controls can be extremely effective in reducing noise exposure, can be implemented quickly, and can be expressly tailored to each community's needs.

Locally imposed in-use controls usually cost less than other controls. It is cheaper to repair an effective exhaust than to modify the whole cooling system to meet Federal regulations. In fact, communities can use financial incentives to encourage construction noise abatement. Higher building permit fees and more documentation can be required if noisy equipment is to be used.

The size of the performance bond can be made a function of predicted noise levels. Local governments, which are often heavily involved with construction, can insist on quiet equipment and operations as a condition for contracts. These types of financial incentives will put pressure on contractors not only to take care of their equipment and the way it is used, but also will motivate them to put pressure on the manufacturers to manufacture quiet equipment.

To facilitate the State and local enforcement of in-use controls major construction equipment noise sources should be labeled. Such a program will provide local enforcement officials with information helpful to determine if a certain piece of equipment is in compliance with the labeled noise standards. Another benefit of labeling is that it enables contractors quickly to ascertain noise levels and perhaps to purchase equipment which will meet local noise ordinances or be less noisy. Also, the previously mentioned financial incentives would be supported through the use of a labeling program.

Another suggested supplement to in-use controls is a second-generation medium and heavy truck regulation. Although this regulation is primarily thought of in terms of lowering surface transportation noise, it will have spillover effects for the construction noise problem.

While some pieces of equipment are used only sparingly during different phases of construction, trucks are present in all phases of construction. Exhibits II-3 to II-6 of Section II indicates the extensive use of trucks at construction sites. Moreover, EPA found that trucks in an average operating condition emit sound levels approximately 81 dB to 94 dB at 50 feet. (See Exhibit II-14). At these levels trucks are only exceeded by pile drivers and rock drills. The latter pieces are generally used less frequently than trucks. Specifically, during the excavation phase of construction several trucks with their engines running are generally in line to be loaded. Others are entering and leaving the construction site spreading noise to the surrounding community and areas beside the roads travelled. Many of these trucks are operated with defective exhaust systems adding to the noise exposure, especially the intrusive aspects of noise exposure. A new truck regulation is suggested because technology at a reasonable cost is available significantly to reduce emission levels. It is proposed that the new truck regulation be accompanied by an acoustical assurance period.*

The regulation, however, will not entirely solve the construction noise problem since many noisy pieces of equipment are often used at the same time. It is, however, expected to make a major impact on sites during phases of construction when trucks are the predominant noise source and along routes travelled by trucks. It must be noted that noise relief from a truck regulation will not come quickly because it takes a long time for quiet trucks to penetrate the fleet. Moreover, there is difficulty of enforcement and probably will never be a very effective after-market enforcement program.

These disadvantages can be reduced when the truck regulation is used as a supplement to the previously proposed in-use controls. Together with the regulation and strict enforcement of State and local in-use controls significant reductions in construction noise can be realized.

Acoustical assurance period refers to a manufacturer assurance that a particular truck will meet certain acoustic levels for a period of time or use.