N-96-01
II-A-243

EPA-5-72 PO 134

Program

NTID300.14

UNITED STATES · ENVIRONMENTAL PROTECTION AGENCY ·

THE ECONOMIC IMPACT OF NOISE

DECEMBER 31, 1971

U.S. Environmental Protection Agency
Washington, D.C. 20460

N-96-01
II-A-243

NTID300.14

THE ECONOMIC IMPACT OF NOISE

DECEMBER 31, 1971

THE NATIONAL BUREAU OF STANDARDS
under
INTERAGENCY AGREEMENT

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

Abstract

A study has been undertaken to survey the economic impact of noise. Data available on the entire subject of noise and its abatement are so rudimentary that they do not lend themselves to even the most primitive economic analysis. It is demonstrated that the number of sources of noise in homes, in industry, on the highways, and in the air. is growing at a dramatic rate. These noise sources are heterogeneous and transient, and, therefore, a universal solution for abatement of noise at the source is not available. From the economic viewpoint, it has been demonstrated that substantial costs are associated with noise and its abatement. Costs such as those associated with equipment redesign, right-of-way, and receiver insulation are discussed in detail. The most glaring data gaps highlight the need for research into the relationship between noise, its abatement, and its impact on: wages, prices, productivity, production costs, employment, balance of payments, real property values, and health. Research using the principles of economics must identify and analyze the most cost-effective alternative solutions to noise. A discussion of spending for noise research is included in the study.

TABLE OF CONTENTS

ANALYTICAL TABLE OF CONTENTS

ANALYTICAL TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

Section I

Introduction

The purpose of this study is to provide an overview of the economic impact of noise and noise abatement in the residential and industrial environments. The first part of the study briefly reviews estimated rates of growth of selected noise generators that are external to the home (e.g., aircraft) as well as products used within the home. The next two sections concern the noise sources that create the most annoyance in the residential environment: aircraft and motor vehicles. In the case of aircraft noise, an attempt is made to estimate the aggregate cost of noise and also the cost of abatement from several different approaches. Some of the benefits to be derived from the abatement of aircraft noise are also considered.

Estimates are given of the number of people subject to noise from products used within and around the home. Because noise can contribute to both fatigue and stress, which are associated with accidents and injuries, a very rough first approximation is made under a number of assumptions of the cost of noise in the home environment. Relative to aircraft noise costs, these estimates are small in magnitude. Estimates are also made of the magnitude of the industrial noise problem.

Some data are presented on the resources devoted to noise research by the government, individuals, and private industry. As measured by a surrogate, patents, the private sector has devoted much more attention to noise than has government during the past decade.

In the final section, the findings of the study are summarized and some recommendations are made for future research. The recommendations for future research are designed to remedy the most glaring defects in the currently available data on the effects of noise and the associated costs.

Because the data at the present time are, at best, fragmentary, the findings of this study should be considered suggestive rather than exhaustive. A number of reasons can be cited for this lack of data. One factor is the nature of noise itself. In contrast to water or air pollution, which can have long lasting effects on the environment, noise pollution "decays" rapidly in both time and distance. As soon as the source of the noise is silenced, the unwanted sound disappears almost instantaneously. Moreover, the intensity of sound diminishes rapidly with distance--a loud roar will be reduced to a muffled rumble by a short distance. A second factor is that the effects of noise are not as "dramatic" or immediate as the consequences of other pollutants. The hearing damage caused by noise generally occurs after exposure over extended periods of time. Also many of the consequences of noise can be attributed to annoyance caused by noise rather than the threat of imminent hearing loss.[1] Thirdly, different individuals exhibit varying levels of tolerance to noise levels. Finally, one of the reasons that noise has not been viewed as a form of pollution is the attitude of the public toward noise as the "price of progress." The noise produced by a product is often associated with efficiency and the ability of a product to perform its designated function, e.g., a "quiet" vacuum cleaner was rejected by a test group because it was perceived to clean less effectively than a noisier model of equal power.

Because many kinds of noise are primarily a source of "nuisance" or annoyance rather than a danger to health, it must be recognized that it might not ever be possible to obtain precise estimates of either the cost of noise or the benefits derived from noise abatement. This is true because nuisance and annoyance are psychological states, which to date have defied adequate quantification by social scientists.

---

[1] Because so many aspects of noise are psychological, researchers encounter the same problems as those found in the theory of consumer behavior. For example, economists and other social scientists have not been able to estimate or to compare the satisfaction or utility that one might derive from consuming three dry martinis and the annoyance or disutility of one's spouse from watching the consumption of three martinis.

Section II

Growth in the Sources of Noise Affecting the Residential Environment

Residential dwellers are constantly subjected to noise generated by products used within and around the home, by noise from "external" sources such as road and highway traffic, nearby industrial plants, and often by aircraft flying overhead. Estimates have been made by investigators of the number of individuals affected by varying levels of noise emanating from a variety of sources.[1] While knowledge of the numbers of individuals affected by noise at a particular point in time is a vital element in determining the scope and magnitude of the noise problem and its effects on society, it is equally important to obtain information which will reveal the future impact of noise. In short, it is also necessary to know the <u>rates of growth</u> of noise in the United States. Growth rates are essential for the estimation of the extent of noise pollution in the near future.

Data have been collected on a variety of noise generators for the years 1959-1970. These data have been used to determine the growth in the number of sources by type and also the growth rate in percent per (see Table II-1). For each of the sources, the raw data and the appropriate estimation equations are given in the Appendix. If it is assumed that no substantial changes are made to reduce the noise levels of each of the sources, then it can be inferred that: (1) the total noise emanating from these sources will increase in approximate proportion to the growth in the number of sources, and (2) that the number of individuals affected will also increase, though not necessarily in proportion to the growth in the sources. Hence, the growth rates of these selected products will provide a first approximation to the growth of total noise in the economy. Four selected areas are considered below: household products, highway and motor vehicle sources, industrial operations, and aircraft noise.

2.1 <u>The Growth in Noise Sources of Home Equipment</u>

Undoubtedly, Americans are among the most gadget conscious individuals in the world. We brush our teeth, dispose of our garbage, shave, wash dishes, clean floors and carpets, and cut our lawns and hedges with power tools. All

[1] Bolt Beranek and Newman Inc. and Wyle Laboratories, Reports to the Environmental Protection Agency, Office of Noise Abatement and Control, 1971. NTID 300-1 and NTID 300-3.

Table II-1

Sales Growth of Selected Home Equipment[a]
1959--1970

Item	Growth in Units/Year (Thousands)	Growth Rate Percent/Year	Years Required for Number of to Double
Automatic Washers	142.2	4.2	17.1
Window Air Conditioners	406.4	14.3	5.0
Power Lawn Mowers	184.8	4.2	17.1
Central Air Conditioning Units	126.6	17.5	4.1
Garbage Disposers	117.5	9.9	7.3
Dishwashers	176.4	15.9	4.5

[a]Derived from data displayed and analyzed in Appendix A.

Sources: Association of Home Appliance Manufacturers; Outdoor Power Equipment Institute, Inc.; Air Conditioning and Refrigeration Institute.

of these items produce noise, some much more than others. In fact, "homemakers" and "handymen" often reject the purchase of quiet products. Noise is associated with power and performance in products such as lawn mowers, vacuum cleaners, and sports cars. Individuals exhibit varying tolerances to noise depending on the nature of the sound and its source.

As an example of the information displayed in Table II-1, consider window air conditioners. The number of window units produced is increasing by over 400,000 units per year. This represents a growth rate of 14.3 percent each year and implies that the number of window air conditioning units sold will double every five years, assuming this rate of growth continues. Not all units are simple additions to the total number of window air conditioners in the nation because some are replacements for old and worn out units. Thus, the rate of growth in the number of units and the absolute percentage growth rate is somewhat overstated, but the implication is perfectly clear: the total noise generated by window air conditioning units will continue to increase in the near future unless efforts are made to reduce substantially the noise output of these units.

The sales growth rates shown in the table vary from 4.2 to 17.5 percent per year. This implies that the total ambient noise produced by some products could double in 4.5 years, whereas others will take more than 17 years to double. Central and window air conditioning, dishwashers, and garbage disposers are among the most popular kinds of home equipment surveyed and also among the noisiest. The sales growth rates of power mowers and automatic washers are considerably lower. Although the length of exposure during use of these products is not of sufficient duration to cause deafness or permanent hearing damage, the rapid growth in the use of mowers and dishwashers is likely to increase the annoyance associated with the noise they produce. In the future, the average American will probably have to contend with increased noise levels generated by increased numbers of powered appliances in his home and in the homes of his neighbors.

2.2 Noise Generated by Highway and Motor Vehicle Sources

In addition to being the most gadget-minded people in the world, Americans are also the most mobile. The Bureau of the Census reports that 29.3 percent of all households in the United States owned at least two automobiles in 1970, compared with 16.4 percent in 1960. Also, 79.6 percent of all households owned at least one car in 1970.

In Table II-2 growth rates related to transportation

Table II-2

Growth Rates of Selected Statistics Related to Surface Transportation Noise, 1959 - 1970

Item	Units	Average Growth in Units Per Year	Average Growth Rate in Per Cent Per Year	Year Required For Number of Units to Double
Automobile, Bus, and Motorcycle Miles of Travel	Millions of Miles	28,897	4.2	17.1
Truck Miles of Travel	Millions of Miles	8,192	5.2	14.0
Value of New Construction	Millions of Dollars, 1957-1959 Prices	1,306	2.3	31.0
Value of New Street and Highway Construction	Millions of Dollars, 1957-1959 Prices	140	2.3	31.0
Total Motor Vehicle Registrations	Number in Millions	3.43	4.0	18.0
Automobile Registrations	Number in Millions	55.78	4.0	18.0
Truck or Bus Registrations	Number in Millions	0.62	4.2	17.1
Motorcycle Registrations	Thousands of Units	192.5	16.9	4.2

Source: Appendix Table A-2 and A-3.

X8423

noise are shown. With a growth rate of 192,500 units per year, motorcycle registrations is the most rapidly growing of the series. This implies a 16.9 per cent annual rate of growth and suggests that the number of motorcycles and their probable contribution to the noise problem will double in slightly more than four years.

Although the growth rates are much lower for all of the other series, the increase in the number of units each year is quite high. For example, the total number of motor vehicles registered is increasing by an average of 3.43 million units per year. Not only are the increases in the number of units substantial, but it is also true that the number of passenger miles driven per vehicle is increasing. Therefore, noise from motor vehicles is increasing as a result of growth in both absolute numbers of vehicles and as a result of increasing usage of those vehicles. Noise emission from the automobile will grow substantially and, with population concentrations in urban areas, the automobile population will centralize in densely populated areas. In the near future, noise from motor vehicle transportation will likely become an increasing source of irritation to urban residential dwellers.

2.3 The Growth of Noise Sources Related to Industrial Operations

There are insufficient data at present to judge the adverse effect of noise from industrial plants and operations on the residential environment.[2] Certain kinds of industrial operations, such as construction, clearly have an impact on the residential dweller. Street repair, construction of new homes, sewers, and building impinge on the home environment or on the individual while at his workspace or in transit. Estimates indicate that millions of people are exposed to construction noise each year.[3]

As shown in Table II-3, the number of various kinds of earth-moving equipment, particularly noisy construction machines, are growing at rapid rates. The number of wheel tractors, for example, will double about every two years, if present trends continue. Similarly, the number of wheel loaders will double approximately every five years. Clearly,

[2] Noise can be considered as an unwanted by-product of energy consumption. It can be conjectured that the trend in noise growth will closely follow the trend in energy utilization patterns.

[3] Bolt Beranek and Newman Inc. A Report to the Office of Noise Abatement and Control, Environmental Protection Agency, 1971.

Table II-3

Growth Rates of Selected Kinds of Earthmoving Equipment, 1960 - 1970

Item	Growth in Units Per Year (Nos. of Machines)	Growth Rate in Per Cent Per Year	Years Required for Number of Units to Double
Crawler Tractors	1088	9.6	7.5
Crawler Loaders	313.8	5.9	12.3
Wheel Tractors	227.3	33.0	2.2
Wheel Loaders	1000.4	15.1	4.9
Scrapers	226.3	9.9	7.3
Rollers	363.9	8.7	8.3
Graders	261.3	6.9	10.4

Source: Associated Equipment Distributors.

unless steps are taken to abate the noise output from such equipment, construction machinery will become an increasing source of annoyance to even larger numbers of individuals.

2.4 Growth in Aircraft Noise

Probably no other source of noise has generated more irritation to the homeowner than that from reciprocating and jet aircraft engines. Aviation noise is of such intensity that the annoyance caused by this noise source has resulted in lawsuits, damage claims, and numerous complaints. Noise disturbance is perhaps exemplified by aircraft noise and, from all indications, the aircraft noise problem will be magnified by the growth of the industry unless significant reductions in the noise emanating from jets are achieved. The most extensive study of the past and future growth of aviation was jointly prepared by the Department of Transportation and the National Aeronautics and Space Administration in 1971.[4]

In the period 1939 to 1969, domestic air transport passenger plus cargo traffic increased at an average annual growth rate of about 18.1 percent. This rate of increase exceeded by four times the growth rate of the general U. S. economy and all other modes of domestic travel.[5] DOT-NASA predicted that by 1985 the total number of passengers enplaned would grow to approximately 800 million as compared to 154.4 million in 1969. (This does not imply that the number of operations will increase proportionately due to the introduction of the Jumbo Jets with increased revenue passenger mile capacity.) Incredibly, air cargo shipments will expand at an even faster rate, since a 1200 per cent increase was forecast for the period 1969 to 1985.[6] DOT-NASA have also estimated that, in 1968, 1300 square miles of land containing 15 million individuals were exposed to undesirable levels of aircraft noise; for 1978, it was projected that the land areas affected would rise to 1800 square miles encompassing 24 million individuals.[7] It is evident that the number of people affected will grow substantially within the decade and that the problems associated with aircraft noise will be expanded considerably. The economic consequences of noise emission from aircraft are discussed in detail below.

---

[4] Joint DOT-NASA Civil Aviation Research and Development Policy Study, Supporting Papers, March 1971, DOT TST-10-5, NASA SP-266.

[5] Ibid., p. 2-5

[6] Ibid., p. 2-4

[7] Ibid., p. 7-11, ff.

2.5 Growth in the Sources of Noise: A Summary

From the sample survey of the growth in noise sources presented above, it is found that the sources of noises are expanding at a rapid rate. Within the decade, the average individual will be more frequently subjected to undesirable noise levels at all hours of the day. Many products (e.g., dishwashers, motorcycles) exhibit very high percentage growth rates and, those items with much lower growth rates (e.g., motor vehicle registrations) are still experiencing substantial increases in the absolute number of units each year. The noise from aircraft will probably increase at increasing rates, unless abatement efforts are undertaken, because of the exceptional growth of the aviation industry. Indeed, if the experience of aircraft noise can be considered a harbinger of things to come, then the effects of noise and the attendant economic impact could have widespread consequences. (See the discussion of the cost of aircraft noise below.)

The growth in the number of sources producing noise is only one side of the total picture. The current trend toward increasing population density in settled areas compounds the problems generated by noise sources: the greater the concentration of people, the more the utilization of noisy products per unit area and the higher the ambient noise level. Not only are noise levels positively related to the density of population, but it is also true that more individuals are affected by a given noise source when population density is high. Thus, increasing population density compounds the problem produced by the growth in noise sources, or one might say that the "noise-density" is growing. In 1920, there were 34,616 urbanized areas which contained 32.6 per cent of the total U. S. population; by 1970, there were 115,575 such areas, a fourfold increase, encompassing 56.2 per cent of the nation's population. By 1980, it is projected that there will be 148,030 urbanized centers in which 61.6 per cent of the population lives.[8] In general, it can be concluded that people will be using more products that generate noise and, because of increasing population density, this noise will affect a greater number of people per unit area.

Although the consumer has not yet expressed a strong preference for quiet in the marketplace by buying less noisy products, this trend is unlikely to continue. As the average level of ambient noise increases along with associated annoyance, the consumer's awareness that "quiet is not a free

[8]Jerome P. Pickard, "Dimensions of Metropolitanism," Research Monograph 14, Urban Land Institute, 1967, p. 47.

resource" is likely to grow. Essentially, this has been the case with both water and air pollution. Though both water and air pollution have been in evidence for decades in the U. S., only recently has the public begun to demand a cleaner environment and a reduction in the amount of pollution. It is clear that clean air and water are no longer so abundant that pollution of these resources can be continued. It is likely the public awareness of noise as a pollutant will extend to other noise sources rather than just jet aircraft as the average noise level continues to increase.

Section III

The Economics of Aircraft Noise

Due to its intensity, the noise from jet aircraft has received the most attention from researchers. Complaints about jet noise have resulted in studies of property values near airports, the insulation required to achieve varying degrees of noise reduction in the home, and in efforts to produce a quieter jet engine. Because of such research, data are available which permit estimates to be made of the cost of aircraft noise, the cost of abatement, and the economic benefits which could accrue from aircraft noise reduction. These topics are considered below.

3.1 The Cost of Aircraft Noise

Noise emission produced by jet aircraft has probably produced the greatest irritation and concern among residential dwellers. This concern has manifested itself in litigation against airports for compensation for loss of property value, easements, and noise damage suits. Court awards for easement and damage suits therefore provide a set of objective measures which can be used to assess the cost of this source of noise. Some studies have also been made of the loss in property values due to aircraft noise pollution. Not only does jet noise affect the home, but it also disrupts other residential activities, e.g., elementary and secondary schools, hospitals, and libraries.

No estimate has been made of the aggregate cost of aircraft noise and data are available only for specific case studies at particular airports. These data can be used, however, to provide a reasonable appraisal of the total cost of aircraft noise to the American society. Most of the case studies are for very large airports, e.g., Los Angeles International, San Francisco International, New York's Kennedy International, and Chicago's O'Hare International. These airports are not only large in absolute terms, but are also experiencing very rapid growth. In the tables below, data are presented for the decade 1958--1968 on the number of passengers handled and also the total number of operations by type at each of the four airports mentioned above. From this information, two facts are readily evident. First, each of the airports has experienced a tremendous growth in total operations over the 11 year periods and, secondly, the number of air carrier passengers has increased far out of proportion to the number of operations due to the increased capacity of the aircraft. If the growth rates for these

Table III-1

Air Carrier Passengers and Aircraft Operations
Chicago O'Hare International Airport: 1958 - 1968.

Year	Scheduled Air Carrier Passengers[a]	Aircraft Operations: Total	Air Carrier	General Aviation	Military
1958	1,261,376	236,060	66,205	91,070	78,785
1959	2,124,769	234,983	82,417	95,407	57,159
1960	5,690,062	244,479	163,351	59,056	22,072
1961	9,514,836	318,526	235,908	66,547	16,071
1962	13,298,710	417,380	331,090	75,300	10,990
1963	15,983,721	426,994	358,266	60,939	7,789
1964	18,203,111	460,227	389,640	63,335	7,252
1965	20,735,834	519,430	443,026	69,923	6,481
1966	22,539,957	562,975	478,644	78,124	6,207
1967	26,408,215	643,787	573,506	65,691	4,590
1968	29,017,458	690,810	628,632	57,428	4,750

[a]Note: Introduction of the commercial jet aircraft fleet began in the late fifties, hearalding the onset of a major new noise source.

Source: Federal Aviation Administration, Statistical Handbook, 1969, p. 83.

Table III-2

Air Carrier Passengers and Aircraft Operations,

Los Angeles International Airport: 1958 - 1968.

Year	Air Carrier Passengers	Aircraft Operations			
		Total	Air Carrier	General Aviation	Military
1958	4,846,884	324,194	226,448	50,908	46,838
1959	5,893,387	316,068	234,446	54,505	27,117
1960	6,605,036	290,862	217,922	51,295	21,645
1961	6,947,206	324,993	235,039	68,910	21,044
1962	7,632,458	344,053	260,515	65,881	17,657
1963	9,094,155	358,749	285,824	57,994	14,931
1964	10,696,392	365,536	289,744	61,566	14,226
1965	12,578,909	374,757	288,610	73,305	12,842
1966	15,251,272	415,433	321,182	83,011	11,240
1967	18,125,152	482,774	384,656	88,296	9,822
1968	20,346,011	594,486	438,386	145,284	10,816

Source: Federal Aviation Administration, Statistical Handbook, 1969, p. 85

Table III-3

Air Carrier Passengers and Aircraft Operations,

San Francisco International Airport: 1958 - 1968

Year	Air Carrier Passengers [a]	Aircraft Operations: Total	Aircraft Operations: Air Carrier	Aircraft Operations: General Aviation	Aircraft Operations: Military
1958	3,595,023	205,210	128,421	55,834	20,955
1959	4,111,220	235,229	139,754	73,776	21,699
1960	4,637,035	235,944	146,022	75,486	14,436
1961	4,754,327	211,852	142,532	55,290	14,030
1962	5,434,226	224,371	158,929	53,150	12,292
1963	6,414,620	238,691	171,431	54,396	12,864
1964	7,459,461	250,859	187,783	52,512	10,564
1965	8,706,984	265,446	210,948	48,927	5,571
1966	10,145,309	291,069	226,867	58,584	5,618
1967	12,248,051	373,429	268,486	49,658	5,285
1968	13,544,414	353,255	297,588	50,529	5,138

Source: Federal Aviation Administration, Statistical Handbook, 1969, p. 85

[a] Includes non-scheduled passengers

Table III-4

Air Carrier Passengers and Aircraft Operations,

John F. Kennedy International Airport: 1958 - 1968

	Air Carrier Passengers		Aircraft Operations			
Year	Scheduled	Non Scheduled	Total	Air Carrier	Aviation	Military
1958	5,821,744	127,679	215,683	191,231	21,578	2,874
1959	6,988,451	73,860	239,836	209,043	26,831	3,962
1960	8,812,642	110,334	274,184	239,617	32,056	2,511
1961	10,226,960	39,835	290,134	256,182	31,774	2,178
1962	11,453,117	57,273	319,265	282,470	34,630	2,165
1963	12,692,831	58,742	339,424	303,818	33,748	1,858
1964	14,487,078	128,861	367,139	328,396	37,223	1,520
1965	16,052,953	155,125	389,917	352,469	35,640	1,808
1966	16,872,035	214,176	438,670	390,898	45,514	2,258
1967	19,738,885	249,685	481,458	403,981	76,000	1,477
1968	19,176,810	396,818	465,120	398,466	65,452	1,202

Source: Federal Aviation Administration, Statistical Handbook, 1969, p. 80

Table III-5

Summary of Growth Rates at Four Selected Airports, 1958 - 1968

Airports	Per cent of Increase in Total Operations	Per cent of Increase in Passengers
Los Angeles	180	420
San Francisco	170	375
Chicago: O'Hare	290	2,300
New York: Kennedy	215	330
Average	215	860

airports shown in the summary tables continue, the noise exposure around these selected airports will increase rapidly during the decade of the seventies. Therefore, the estimate of the cost of aircraft noise can be considered as a conservative approximation.

For these four airports, aircraft operations increased an average of 215 per cent in the period 1958 - 1968. In the same period, however, the average per cent increase in passengers arriving at and departing from these airports increased four times as fast. Thus, while the jet noise problem at large urban airports is growing at a rapid rate, the noise generated by passengers arriving and leaving the airports (and the associated automobile traffic) is growing much more rapidly. These data lend additional support to the earlier finding that noise surrounding airport activity will increase significantly in the near future unless efforts are directed toward abatement.

3.2 Easements as a Measure of the Cost of Aircraft Noise

Flyover easements represent compensation to property owners which theoretically reflects the reduced value of real estate due to noise, dust, vibration and other unpleasant effects of aircraft operation. Easements have been obtained by airports in five cities; the pertinent data are shown in Table III-6.

Certain data are not available due to the fact that litigation is still in process. In the Des Moines experience, the city offered to purchase easements for $250 to $300 per parcel. If the owner declined to accept the offer, the city invoked the doctrine of eminent domain and bought the property. The easement was then included as a deed restriction and the property sold to private owners; generally the resale price was from $1500 to $2000 less than the city's purchase price. At Seattle, the city, by inverse condemnation, acquired easements based on the price differentials for similar parcels removed from airport noise, which cost approximately 15 to 20 per cent of fair market value. It is interesting to note that for vacant land the cost of the easement was about 40 per cent of fair market value, "because the property was subject to so much noise that no FHA loan could be obtained for a new structure and there was no low-rent housing market in the area for rental development."[1] No data other than the range of the easement costs are available for Jacksonville, Florida.

---

[1] McClure, Op. Cit., p. 28

Table III-6

Cost of Flyover Easements at Five United States Airports.

City	Number of Easements	Maximum Paid	Minimum Paid	Range	Average
Columbus, Ohio	30	$6,670	$ 870	$5,800	$2,414
Denver, Colorado	32	1,751	931	820	1,000
Des Moines, Iowa	--[a]	2,000	1,200	800	---[a]
Seattle, Washington	--[a]	---[a]	---[a]	---[a]	4,200
Jacksonville, Florida	--[a]	9,000	250	8,750	4,625

[a]See Text, infra.

Source: Paul T. McClure, "Indicators of the Effect of Jet Noise on the Value of Real Estate," The Rand Corporation, Santa Monica, California, July 1969.

It has been estimated that in 1968, 15 million individuals were subject to undesirable levels of aircraft noise; moreover, it is projected that, by 1978, almost 24 million people will be affected.[2] If it is assumed that the average family size is four persons and that each family represents a dwelling unit then, from the 1968 estimate of the number of individuals affected, it follows that approximately 4 million parcels of land are potentially subject to compensation for easements. The estimated total cost can be obtained from the average of the easement costs shown in Table III-6. The approximate total easement costs range from $4.0 billion to $18.5 billion, depending upon whether one uses the average from Denver or from Jacksonville. For 1978, the cost range would be from $6.0 billion to $27.75 billion, assuming that 24 million people are affected. Thus, as a first approximation, one could argue that the cost of aircraft noise pollution, based on easement costs, is at least $4.0 billion presently and could easily reach $27.75 billion within the decade.[3]

3.3 Litigation as a Measure of the Cost of Aircraft Noise

In the 1962 Griggs vs. Allegheny case the precedent was established that the rights of airport neighbors were being taken by airport operations.[4] Since that time, many suits have been brought against airports for the illegal "taking" of property. Only the litigation against Los Angeles International Airport will be reviewed here, however, since it is typical of airport litigation. The damages sought are for inverse condemnation, personal injury, and property damage. Suits have been filed by individuals, groups of individuals, and organizations. The relevant statistics are summarized in Table III-7.

---

[2] DOT-NASA Joint Study, Op. Cit., p. 7-11

[3] The easements were obtained over a period of years. In the Columbus case, seven of the easements were obtained in May 1967. See McClure, Op. Cit., p. 25. The estimates given in the text do not account for price increases or real estate appreciation which has occurred since these easements were obtained. Hence the estimates in the text should be considered as conservative.

[4] 369 U. S. 84 [1962].

Table III-7

Summary Statistics on Litigation Against Los Angeles International Airport, 1960's[a]

Litigant	Number of Households	Total Damage Claimed	Range	Average Damages Per Household
Individuals	30	$ 3,342,725	$ 1,148,950	$111,428
Groups of Individuals	594	11,189,000	3,928,000	18,837
Organizations	61,212	2,800,000,000	2,300,000,000	45,743

[a]Some of the cases are still pending.

Source: McClure, P. 30ff.

Any estimate of aggregate damages based upon litigation would be an astronomical sum. If 4.0 million households are subjected to noise from aircraft that could be compensable by the lowest estimate of the average damages shown in the table, then the total cost of aircraft noise pollution would be in the neighborhood of $75.2 billion. It is clear that the plaintiffs have added an ample measure of "blue sky" to the damages sought, which inflates the aggregate estimate. Nevertheless, if the claims were settled out of court on the basis of 10 per cent of the sums asked in damages, the total cost of aircraft noise would be about $7.5 billion--hardly an insignificant amount, and certainly well within the range of estimates derived from the "easements indicator" of total cost.

3.4 Loss in Property Value as a Measure of the Cost of Aircraft Noise

Two studies have attempted to measure the loss in property values caused by aircraft noise emission.[5] One study, conducted in the Los Angeles area, attempted to determine the decrease in the appreciation in property due to jet noise. It was assumed that proximity to an airport increases property values, but that noise decreases those values. The second study, concerning the San Francisco area, sought to evaluate the relationship between several measures of property value and the amount of exposure to aircraft noise. Rather than review the methodology of each study, only the principal findings are presented here.

In the Los Angeles report, eight sample areas were chosen--four subject to high levels of noise and four comparable areas which were not subject to jet noise. The mean annual changes in sales prices of the residential property between the two types of areas were analyzed for the period 1955 through 1967. It was found that there was no statistically significant difference between the rate of appreciation in homes with high noise levels and those in "quiet" areas. The investigator, however, pointed out a

[5] The Los Angeles study was conducted by Bolt Beranek and Newman, Inc. The data were presented in City of Los Angeles vs. Matson, 1966. The San Francisco study was authored by Paul K. Dygert, "On Measuring the Cost of Noise From Subsonic Aircraft," The Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, 1970.

number of facts which may have biased the findings. First, the turnover rate in quiet areas was considerably less than that of high noise areas. Property in quiet areas changed hands only 62 per cent as fast as in noise affected areas. Since appreciation in value is reflected through sales prices, the appreciation of property in quiet areas was biased downward, which would, in effect, make the relationship between noise and property difficult to ascertain. Moreover, this implies that noisy areas are less stable communities than quiet ones and this can be one of the costs associated with noise. A less stable community is more likely to deteriorate aesthetically than one which is stable. Secondly, individuals who travel often by air may be willing to forego the unpleasantness of noise in order to have ready access to air travel. Given a choice, these individuals would prefer quiet to noise and, if the noise were significantly abated, the value of property would likely appreciate much more rapidly near airports. Thirdly, there is a tendency for commercialization to develop around airports, e.g., hotels, car rental agencies, parking lots, etc., and while noise may adversely affect the property value for <u>residential</u> use, the potential gain from commercialization may well contribute to offsetting this decrease. Therefore, not only may residential neighborhoods near airports be less stable, their very structure may change to a commercial development. One would be hard pressed to prove that high noise levels (regardless of the source) enhance the value of <u>residential</u> property.

The San Francisco study analyzed four measures of property values (mean property value, median property value, mean land value per square foot, and median land value per square foot) as a function of some 24 other variables, one of which was the average noise level. In each case where the noise level significantly affected property values, the average noise level was shown to have a detrimental effect, i.e., property value was reduced because of noise. In a majority of cases, the noise variable was a statistically significant determinant of property values.

Unfortunately, it is impossible to derive any estimates on the loss in property values from either of the two studies. The qualifications which were stated in the interpretation of the Los Angeles study also apply to the work done in the San Francisco area. These studies point out the need for more complete and comprehensive research on the economic effects of external noise sources.

3.5 The Impact of Aircraft Noise on Schools and Other Community Activities

Although most of the attention directed toward the effects of aircraft noise pollution has been focused on the household, other activities in the residential environment, such as education, are also seriously affected. For example, the Los Angeles Unified School District is seeking $95 million in aircraft noise damages. Moreover, schools in Los Angeles have had to be closed and the students relocated; others have had to be insulated against sound. One elementary school and one junior high were purchased by the Los Angeles airport. Total relocation and classroom construction costs for the affected 1590 pupils was $951,000. The estimated abatement cost on 28 noise affected schools (26 from aircraft, 2 from freeway) is $9.08 million, in 1968 prices.

The severity of the problem, however, is best illustrated by the following citation from a study of New York's J.F.K. International Airport and environs made by the National Academy of Sciences.

> One of the most insidious aspects of aircraft noise pollution in the environs of Kennedy Airport is the penalty it imposes upon children in public and private schools. The periodic inundation of schools by high levels of aircraft noise has the critical effect of reducing the net effective teaching time available to students during the school year. This results from the fact that many overflights of public and private schools in the environs of the airport produce a total eclipse of communications in the classrooms, even with the windows closed. This intrusion of aircraft noise necessitates a pedagogical approach known somewhat bitterly among teachers and school officials in New York region and elsewhere as "jet-pause teaching." Without detailing the minute-by-minute interference of airport operations upon noise-impacted schools in the airport environs, it is difficult to provide precise quantitative estimates of the daily interference that results. Experience has shown, however, that substantial speech interference with school operations occurs in areas within the zone of NEF 30 unless "sound conditioning" measures are employed in school construction.
>
> At least 136 public schools of the New York City School system are located within the zone of NEF 30 for Kennedy Airport. School utilization

for 1969 furnished by the New York City Planning Commission indicate that about 172,000 pupils attend these schools each day. An additional 85 private schools are also located with the NEF 30 zone in New York City and at least 12 more public and private schools are within this noise exposure zone in Nassau County. The combined total enrollment of public and private schools located within the zone of NEF 30 is conservatively estimated at 275,000 pupils. Variations in flight patterns at the airport from day to day have the effect of distributing the noise burden among the many schools within the zone of NEF 30, and the degree of interference with classroom communications is considerably less for schools at the outer margins of the zone for some of those, such as P.S. 42, 105, 146, and 181, and JHS 198. In some of the latter schools, in heavily impacted areas such as Howard Beach, the Rockaways, Rosedale, and Inwood, teachers complain that brief instructional periods must be sandwiched between frequent interruptions by aircraft noise.

On a typical day in Arverne, planes were observed approaching the airport at low altitudes at approximately two-minute intervals during an hour in the early afternoon. With each overflight, a 20-second interval of noise from the passing aircraft was sufficient to eliminate all except shouted communications on the school site and in typical classrooms with windows closed. Thus, ten minutes of the hour, or about 17 per cent of a typical 50-minute class period, were sacrificed to environmental noise pollution. For pupils in schools in such noise-vulnerable locations, this translates into the loss of more than an entire school day each week, the actual lost time depending upon the pattern of traffic flow at the airport. While this example illustrates one of the extreme situations of aircraft-noise exposure in the environs of Kennedy Airport, its implications for the impact of environmental noise on education throughout the zone of NEF 30 are clear. This analysis is limited to actual time lost to pupils and teachers as a result of air-induced fatigue or irritability, both well-known effects of noise on humans, nor does it take into account any higher rate of teacher turnover in the school system as still other community costs of aircraft noise.[6]

It would be difficult, if not impossible, to assess accurately the economic costs associated with the impact of aircraft noise on the classroom. In the case of Kennedy airport, one could perhaps argue that large numbers of class days of education for pupils are lost each year due to noise interference. This could be evaluated by determining the loss in effective teaching time and turnover rates for teachers, but such costs reflect only the "tip of the iceberg." The true social cost is the loss in educational opportunity and learning capacity of students caused by the interference. If a student's learning capacity is reduced or his performance adversely affected by noise, this could easily impede his academic motivation and achievement, and be reflected in his earnings stream over his entire lifetime. It is impossible to obtain data on such costs, but it is highly likely that they are being borne by students around major airports throughout the country, because of the presence of jet noise.

One can cite many instances of other activities that occur within the community that are adversely affected by aircraft noise. For example, outdoor public concerts have traditionally been held at Watergate, along the Potomac River, in Washington, D. C. Due to jet noise from National Airport, it was announced in August 1971, that no further concerts would be presented. This is but one example of how aircraft noise degrades the outdoor environment and disrupts or forces discontinuance of community activities.

3.6 Cost of Aircraft Noise Abatement: Insulating the Receiver from the Source

With regard to aircraft noise, there are two ways to insulate the receiver from the source. Either land can be purchased around airports to provide a "noise right of way" which would protect individuals from takeoff and landing noise, or the homes within areas which are subjected to undesirable noise levels (usually 30 NEF or greater) can be insulated to achieve various levels of noise reduction. It should be noted that the latter alternative makes no provisions for the effect of noise on the outdoor environment, for it requires individuals to remain inside acoustically

[6] National Academy of Sciences, "Jamaica Bay and Kennedy Airport: A Multidisciplinary Environmental Study," 1971, Vol. II, pp. 95-96.

treated homes to avoid the annoyance caused by aircraft operation.

The total cost of providing a noise right of way around airports is the sum of acquisition costs of the land and the relocation costs of individuals. In 1971, the Department of Transportation and the National Aeronautics and Space Administration (DOT-NASA) estimated that 1,300 square miles of land in the U. S. are presently affected by noise exposures corresponding to 30 NEF or greater due to aircraft operations. If the land were purchased for an average of $20,000 per acre, the cost of land acquisition alone would be $17 billion.[7] The cost of relocation services, allowances, moving and property transfer payments were estimated on the basis of the precedent set in the Federal-Aid Highway Act of 1968 which provides $2500 per household or $625 for each member of a family of four for these expenses. "If the Government were to apply a similar cost of $625 per person for noise rights-of-way, the system-wide social cost would be $9.4 billion to cover the 15 million people presently affected by noise levels of 30 NEF or higher."[8] Thus, the total cost of aircraft noise abatement achieved by land acquisition might total approximately $26.4 billion dollars.

Efforts are currently underway to initiate the construction of a noise right of way around Los Angeles International Airport, as reported by the Washington Post, on September 11, 1971 (p. D.46):

> The city of Los Angeles is spending almost $300 million to "eradicate" 1,994 private homes around the ocean coast airport, the nation's second busiest, to cope with the protest over the noise of jetliners.
>
> The city is buying the homes, a number with fine sea views and swimming pools, at prices ranging from $28,000 to $115,000. The homes are located on over 400 acres in the outskirts of Los Angeles International Airport, which is exceeded only by Chicago's O'Hare Field in volume of traffic.

---

[7] Joint DOT-NASA Study, *Op. Cit.*, p. 7-12.

[8] *Ibid.*, p. 7-13.

This is the most extreme method ever devised to deal with airport noise; the city bought one house for $97,000 and paid a wrecking company $360 to destroy it. The project will take almost two years and when it is finished, only bare land will remain. The purchases are being financed by 30-year revenue bonds. In addition to homes other buildings are being destroyed. One school covering a 10-acre square of ground was demolished.

Some of the houses are being sold at prices ranging from $300 to $3,000 to individuals and developers to be moved elsewhere. The noise of the landing craft is heard far from the immediate surrounding area, particularly in the communities of Inglewood and El Segundo, and no program has been initiated for those tens of thousands of residents.

These cost estimates can be considered conservative, because they ignore the subsequent impact that the dislocation of 15 million individuals would produce within the economy. If the average family were composed of 4 persons, nearly 4,000,000 dwellings would have to be found to accommodate those dislocated. This is nearly ten times the number of new starts of private metropolitan housing in the U. S. for the year 1968.[9] The impact on the home construction industry would be substantial, for undoubtedly the shortage of housing that currently exists would be greatly intensified and the price of homes as well as mortgage interest rates would rise, substantially, further compounding inflation. The direct cost estimate of $26.4 billion dollars (in 1968 dollars), therefore, ignores many indirect costs and consequences such as the effects on the housing industry, mortgage interest rates, and prices.

The second alternative for insulating the individual against aircraft noise pollution is to insulate the home. In 1966, a study was conducted for the Department of Housing and Urban Development, Federal Housing Administration, of the costs of insulating an existing home from bothersome aircraft noise.[10] A similar study was made for the

[9] Source: Bureau of the Census.

[10] Bolt Beranek and Newman, Inc., "A Study--Insulating Houses from Aircraft Noise," Housing and Urban Development, Federal Housing Administration, 1966.

Los Angeles International Airport.[11] The BBN study produced cost estimates for a 1000 square foot home which varies by type of construction and the level of noise reduction desired. The LA study determined the cost of making aircraft noise totally imperceptible within the hypothetical 1200 square foot seven room, $24,000 stucco house exposed to 100 PNdB.

The results of these studies are given in the three tables below (Table III-8, Table III-9, and Table III-10).

Table III-8

Bolt Beranek and Newman's Estimate of the Probable Range of Modification Costs for a 1,000 Square Foot House, 1966 (Exclusive of Costs for Ventilation)

	Noise Insulation Improvement		
House Type	5-10 PNdB	10-15PNdB	15-20PNdB
Light Exterior Walls (wood, metal, stucco, or composition)	$260 to $820	$1,600 to $2,400	$4,000 to $4,500
Heavy Exterior Walls (brick, masonry, or concrete block)	$260 to $820	$1,600 to $2,400	$2,800 to $3,400

Source: Bolt Beranek and Newman, Op. Cit., p. 54.

[11] See also, "Indicators of the Effect of Jet Noise on the Value of Real Estate," Paul T. McClure, July, 1969, Rand Corporation, Santa Monica, California.

Table III-9

Cost Estimates for Installation of House Air Conditioning for a 1,000 Square Foot House

Type of System	Approximate Installation Costs
Room Units	$500 - $600
Central-Utilizing Existing Ducting	$500 - $900
Central - New Ducting Required	$1,200 - $1,600

Source: Bolt Beranek and Newman, Inc., *Op. Cit*, p. 55.

Table III-10

Estimates of the Cost of Insulation of Homes Against Aircraft Noise

	Work Performed	Cost
STAGE ONE	Seal all windows. Install forced air ventilation. Replace deficient exterior doors. Seal door edges. Install sound traps in door edges. Seal miscellaneous cracks.	$2,695
STAGE TWO	Stage One plus double glaze all windows. Treat roof-ceiling interspace.	$5,522
STAGE THREE	Stage two plus modify inside surface of exterior walls. Modify floor at under-floor interspace.	$8,945

Source: McClure, *Op. Cit.*, p. 20.

On the basis of the information in the tables above, estimates of the cost of insulation of homes can be derived if, as estimated earlier from the DOT-NASA study, it is assumed that nearly 4,000,000 homes are affected by aircraft noise. Cost estimates based on the Wyle studies would range from a low of $10.7 billion to $35.7 billion. The data provided by BBN suggests that the total cost of insulation would range between $3.0 billion and $20.0 billion. The cost estimates were made in 1966-1967 and are consequently biased downward due to price increases which have taken effect since that time.

It is obvious that the cost of insulating houses is on the same order of magnitude as that of land acquisition near airports. The indirect economic consequences of insulation are not as severe as those caused by the relocation of nearly 4,000,000 families. It would seem, however, that neither alternative for reducing the impact of aircraft noise by insulating the receiver is economically viable. Land acquisition and the resulting dislocation of families could have serious consequences on the general economy, but insulation of homes is merely a method of treating the symptom rather than the disease. To escape the annoyance of aircraft, people would have to remain in houses sealed against sound. The outdoors would still be subject to aircraft noise.

3.7 Cost of Aircraft Noise Abatement: Reduction of Noise at the Source

The source of noise from aircraft is the engine, primarily jet engine whine produced by the intake and compression of air and the high velocity expulsion of exhaust. The technology exists to modify current jet engines (retrofitting) by nacelle treatment to achieve significant noise reductions or to equip jet aircraft with high by-pass "quiet" engines. Either alternative is costly, but substantially less than attempting to achieve acceptable noise levels by insulating the receiver. Estimates of retrofit costs have been made by both the Boeing and McDonald-Douglas aircraft companies.[12] The McDonald-Douglas Corporation estimated the cost of each engine retrofit at $655,000 (including spare nacelles). The Boeing Company's estimate for each retrofit was $1 million. It should be noted that a major component

[12] National Aeronautics and Space Administration, "NASA Acoustically Treated Nacelle Program," 1969. See especially pp. 63-73, and pp. 109-117.

of the cost is due to depreciation of the nacelle, which was assumed to have a life of only 5 years while the aircraft itself has an assumed life of 12 years. In other words, both companies make the supposition that each aircraft engine is modified when it is 7 years old. The noise level generated by an airplane as well as the retrofit cost is a function of the number of engines on the aircraft. The cost of retrofit by number of engines and by the two companies are shown below in Table III-11.[13]

Table III-11

Estimated Costs of Retrofit

Number of Engines	Number of Aircraft	Retrofit Cost Boeing	Retrofit Cost McDonald-Douglas
4	816	$3,264,000,000	$2,137,920,000
3	543	1,629,000,000	1,066,995,000
2	422	844,000,000	552,820,000
TOTAL		$5,737,000,000	$3,757,735,000

To install treated nacelles on all jet aircraft would cost between $3.8 billion and $5.7 billion.[14]

[13] Federal Aviation Administration, Statistical Handbook, 1970, passim.

[14] A number of other sources have estimated the cost of retrofitting the jet fleet; these estimates are generally lower than the Boeing - McDonald-Douglas figures. For example, DOT-NASA (Op. Cit., p. 5-6) have estimated the cost of retrofitting at about $1 billion.

3.8 Benefits from the Abatement of Aircraft Noise

The reduction of aircraft noise would produce significant benefits for the millions of individuals exposed to undesirable aircraft noise levels and also, the airline industry. It is difficult to assess accurately the benefits to individuals, because little information is available concerning the costs associated with the effects of annoyance. The adverse effect on property values and the costs of easements would be less, and less litigation should result, if aircraft noise were significantly abated. The benefits accruing to the airline industry are, however, more easily identified and some approximate indications of the benefits can be developed. These factors are reviewed below.

If noise from aircraft were significantly lowered, the cost of construction of new airports and the operating costs of existing facilities could be greatly reduced. Land acquisition is a major expenditure in the development of new airport facilities. If noise levels were reduced, the size of the parcel required to provide the "noise right-of-way" would also be smaller. The savings could be very substantial, according to DOT-NASA estimates:

> The area of land encompassed by the 110 PNdB takeoff contour of a long-haul four-engine civil jet is approximately 600 acres; the additional area of land encompassed by the 100 PNdB contour is approximately 7,000 acreas. Assuming that a typical airport has eight runway ends, a 10 PNdB noise reduction would "relieve" about 50,000 acres. To buy this acreage, assuming a new airport were being established, say, 30 miles from a major city, would cost some $350 million at an assumed cost of undeveloped acreage of $7,000 per acre. Assuming that three new airports were involved, the savings would equal the billion dollars estimated as the cost to quiet the current civil aviation jet fleet.[15]

The above statement from the DOT-NASA study also suggests some further savings. In the estimation of the $350 million saving per major airport, it was assumed that the terminal would be built some 30 miles from a major city. Such airports are inconvenient for the traveler and tend to be under utilized due to the inherent costs associated with time lost and distance involved in reaching the terminal.

---

[15] DOT-NASA Joint Study, Op. Cit., p. 5-6.

This phenomenon is amply illustrated by the case of the Washington, D. C., airports: Washington National is conveniently located and heavily utilized while Dulles International is distant from the population centers which it serves and has excess capacity. DOT-NASA has also estimated that "if the effect of noise were to cause an airport to be located 10 miles further from the populated area it serves, the additional cost to travelers and employees could exceed $30 million annually for each major airport."[16] The more distant the airport from the city, the greater the inconvenience cost and the less the cost of undeveloped land per acre.

There are economic costs beyond merely the cost of construction of airports distant from metropolitan areas that they serve. If the facility is to be a viable entity, then high-speed access links to remote airports must be constructed. The construction of such freeways, highways, or rapid transit systems require the purchase of rights of way and the dislocation of residential communities or industrial facilities over and beyond the cost of construction. There are real economic costs associated with such construction and these should also be noted.

From the growth in the number of aircraft operations and air travel, it is obvious that the number of airports accommodating jet aircraft will grow significantly in the near future. Unless noise abatement measures are undertaken, the cost of new airports and the indirect costs to travelers and employers will be enormous, due to the noise problem.

Existing airport facilities are also affected by the current noise levels of jet aircraft. In particular, airport capacities are reduced in three ways: first, noise limits the number of hours of each day that the airports can be used. For example, jet operations at some airports are not permitted between 11:00 p.m. and 7:00 a.m. This is true of Washington's National Airport; the passenger bound for Washington must deplane at either Dulles or Baltimore's Friendship Airport if his plane is scheduled to arrive during restricted hours at National. This restriction severely limits the airport's efficiency, for nighttime traffic is often shifted to the daylight hours causing higher peak loads and congestion. A new airport may have to be built in order to avoid the overloading of existing facilities during the daylight hours. Cargo and airfreight operations are ideally suited to nighttime traffic and if this must be eliminated due to noise, then the utilization of the civil

---

[16] Ibid., p. 5-5.

aircraft fleet is reduced as is the revenue earning capability of domestic carriers. Secondly, it is common to restrict runway usage because certain runways will expose more individuals to noise than others. Thus, the potential of the existing facilities is lowered and expansion may be hampered solely because of noise. If present facilities cannot be expanded, it may be necessary to build additional airports. Further, aircraft delays, which result in losses of both time and money by passengers and of aircraft capacity utilization by airlines, are often caused by such restrictions.[17] Thirdly, in order to reduce the impact of noise, flight-space restrictions are frequently imposed and certain segments of the airways are not available to the jet fleet. This further reduces the capacity of both airports and aircraft and also contributes to operating delays, which are costly to both travelers and the airlines. DOT-NASA have estimated that noise restrictions alone could reduce the capacity of an airport by 20 per cent.[18] The annual aircraft-delay cost for an airport with 450,000 operations annually has been estimated at $11 million.[19] This is exclusive of the time lost by passengers, the inconvenience of missed connections due to delays, and so forth.

3.9 Aircraft Noise: A Summary

In summary, the benefits from the abatement of aircraft noise accrue to the operators of airports, the airlines, as well as to the residential dweller who no longer is subjected to undesirable noise levels from this source. Most of the economic benefits can be thought of as the elimination, or at least the reduction, of the economic costs of aircraft noise, which in the aggregate have been estimated in billions of dollars in direct costs. The indirect effects and economic consequences of jet noise are equally important. One requirement for the growth and development of a region in economic terms is an adequate transportation system. To the extent that aircraft noise reduces the efficiency of air

[17] Much of airline travel is done for business purposes, as opposed to pleasure travel. Those traveling are often doing so in an executive capacity and are paid commensurably. Therefore, the economic cost of aircraft delays involves the "lost wages" of a relatively high income group.

[18] DOT-NASA Joint Study, p. 5-6

[19] Loc. Cit.

transportation, a major transportation mode, or that the restrictions due to noise make the construction of airports more costly than would be required otherwise, regional economic development could be retarded.

From the estimates given for the cost of aircraft noise abatement, it is clear that noise should be reduced at the source. While the cost of acoustically treating jet engines range from $3.8 billion to $5.7 billion, it was estimated that the cost of insulating houses or providing a noise right of way would be several times as large. With present technology, however, it is impossible to produce a silent jet engine; nor are the prospects for such a technological breakthrough in the near future promising. Therefore, some combination of retrofitting engines, providing noise rights of way around airports, and insulating homes will be required to achieve acceptable noise levels from aircraft at a reasonable cost. From the data presently available, it is not possible to determine the economic tradeoffs or the "optimum" combination of these abatement alternatives for a given locality. In view of the economic consequences of aircraft noise, however, research should be undertaken to provide more adequate knowledge of these tradeoffs.

Section IV

The Economics of Ground Transportation Noise

Ground transportation noise is generated from a large number of sources: automobiles, buses, trucks, ambulances, fire engines, motorcycles, trains, and urban subways. As indicated in the section on growth of noise sources, total motor vehicle registrations are growing at about 4.0 per cent per annum and if that rate continues, will double in less than 18 years. The numbers of truck, bus, and motorcycle registrations are growing at a higher rate than automobile registrations. Growing at almost 17 per cent each year, the number of licensed motorcycles could double in a little over four years. At a growth rate of 4.2 per cent per annum, the number of buses and trucks on the nation's streets and highways could double by 1988, i.e., in 17 years. As in the case of other kinds of noise, ground transportation noise as an environmental pollutant depends on the magnitude of the noise emitted by the source, the path of transmission, and the sensitivity of the receiver. Studies have shown that because of their high noise levels and their frequent penetration of residential areas, trucks, buses, and motorcycles often exceed ambient sound levels.

Broadly conceived, ground transportation emissions can be divided into two groups: (1) the intrusion noise generated from motor vehicles that contributes to the ambient sound, and (2) the noise of freeway or expressway traffic. Both kinds of ground transportation noise vary by time of day and also by weather conditions.[1]

4.1 Noise Distribution: Sources of Noise

In 1969, the State of California conducted an intensive survey on the sources of motor vehicle noise. The survey was conducted to obtain specific data on the number and the types of vehicles that would exceed a proposed reduction in the highway noise limits for vehicles in the State of California.2 Although the survey originally emphasized

---

[1] U.S. Department of Commerce, The Noise Around Us, September 1970, p. 97.

[2] California State Assembly Bill 2254 was introduced in the 1969 Legislative Session by Mr. George W. Millias and Mr. Frank Lantenman. The law proposed a 2 dB(A) reduction in the maximum permissible noise limits for all vehicles. To answer questions that arose during hearings on the proposed bill, the California State Highway Patrol took a noise

passenger automobiles, some information was collected about motorcycles and pickup trucks. The study was divided into two parts: (1) city streets with speed zones of 35 mph or less, and (2) freeways and country roads with speed zones of more than 35 mph. Noise readings were made at 21 locations on city streets, 10 locations on freeways in Los Angeles, and Sacramento, and at four locations on country roads.

City Streets: The survey of 21 different locations on city streets found that the noise level for 9,395 vehicles under 6,000 pounds gross vehicle weight was 68 dB(A)--considerably lower than the California State Statutory limit of 82 dB(A). Only three vehicles, or about .03 per cent of the sample exceeded the statutory limit. Each of the three automobiles had modified exhaust systems. With the exception of Volkswagens, older automobiles (Chevrolets, Dodges, and Fords) averaged approximately the same noise levels as newer automobiles, i.e., those manufactured after 1965.

The Freeway Test: As might be expected, the measured noise level for the 2,865 vehicles tests in the freeway sample was higher than that for the city streets. Nevertheless, the average noise level of 74 dB(A) was less than the statutory limit. Only two vehicles exceeded the statutory limit of 82 dB(A) and each of these vehicles also had a modified exhaust system.

Country Roads: The results of the test for automobiles traveling on asphalt roads in excess of 35 miles an hour with no stop signs, also showed that the measured vehicles had an average noise level (71 dB(A)) that was less than the statutory limit (86 dB(A)).

As a result of the study, the Department of the California Highway Patrol believes that the State Legislature could significantly reduce the maximum statutory noise limit without placing in violation, or an excessively high financial

Footnote 2 Continued

survey to find the answers to the following questions: (1) The average noise levels of vehicles under 6,000 pounds gross vehicle weight rating. (2) The noise level distribution of vehicles under 6,000 pounds gross vehicle weight rating. (3) The causes of the noise from vehicles that exceed the present limits, and (4) The extent to which the proposed lower limits might penalize older vehicles. Department of California Highway Patrol Passenger Car Noise Survey, Sacramento, California, January 1970, mimeographed.

burden on, those automobile owners who make reasonable efforts to maintain their automobile exhaust systems in good condition. Only 15 out of approximately 55,000 automobiles and pickup trucks tested exceed the statutory limit.[3]

4.2 The Cost of Ground Transportation Noise

Because of the convenience of owning and operating automobiles and the convenience of using limited access freeways, society has accepted and even acclimated itself to traffic-generated noise. Nevertheless, the presence of high noise levels can alter consumer choices and may affect the value of certain kinds of real estate, especially the value of properties located close to busy freeways. Two studies, one on the effect of freeway traffic noise on apartment rentals in Portland, Oregon, and another on the effect of such traffic on residential real estate in Toledo, Ohio, shed some light on the cost of noise on property values.

Traffic and Rental Values in Portland, Oregon: The purpose of the Portland study was to measure the effect that freeway noise has on the value of a sample of apartments, holding the effects of other variables constant.[4] A total of 38 different apartments or apartment complexes were included in the study. Each of the apartments met the following criteria: (1) within one mile of the two major freeways in Portland, (2) contained at least 15 apartment units, and (3) had been in use for a sufficient period of time to establish property values. From a total of 81 possible independent variables, the following 25 were used for the stepwise regressions:

Variable

Distance to Shopping Center

Distance to Elementary School

Distance to High School

Distance to Recreation Area

[3] Ibid., p. 23

[4] The Robin M. Towne and Associates, Inc., An Investigation of the Effect of Freeway Traffic Noise on Apartment Rents. A report prepared for the Oregon State Highway Commission and the United States Department of Commerce, Bureau of Public Roads, October 1966.

Variable

Distance to Central Business District

Distance to Freeway Access

Assessed Value of Apartments (1965)

Number of Units in Building

Story of Unit

Index of Quality (mainly elevator, lobby, grounds, swimming pool, and recreation facilities)

Number of Stories in Building

Size of Apartment Area

Size of Site Area

Age of Building

Percentage of Vacant Apartments (1965)

Size of Average Unit Area

Average Unit Rent (1965)

Average Building Vacancy Rate (1965)

The analyses resulted in two principal findings and one general conclusion. The first finding was that freeway noise had greater significance for expanding rent differences for units on or above the fourth floor than those located on the third floor or below. The second finding was that the effect of freeway noise on rents in Portland is fairly small.[5]

The general conclusion of the research group (which was not necessarily supported by the data), was that although freeway noise might be a nuisance, the disutility of that noise is not reflected in rents. This simply means that the subjective disutility of noise is offset by the subjective utility of other determinants of rent. Apartment dwellers may tend to be more transient than home owners. Because of that, it is not unlikely that apartment dwellers have a

[5] Ibid., p. 116.

greater tolerance to noise, especially when noise is offset by other factors such as proximity to schools, places of work, and recreation facilities.

<u>The Effect of the Detroit-Toledo Expressway on Property Values in Toledo</u>: In 1966, the Department of Civil Engineering, Research Foundation, The University of Toledo, studied the effect of freeway noise on the value of residential properties in Toledo, Ohio.[6] The research effort was a continuation of a study conducted in 1965-1966, which investigated 15 different areas between the Ohio and Michigan border. The earlier study determined that the data collected were not sufficiently conclusive to analyze the economic effect of traffic noise on property values. The follow-on study was an in-depth analysis of one neighborhood in Toledo. According to the socio-economic sketch of the neighborhood, it is a lower-to-middle income neighborhood with low rates of crime, lower rates of unemployment, juvenile delinquency, and child dependency on public welfare than corresponding averages in the same county.[7]

The fact that the neighborhood is not a cross-section of the population, representing low, middle and high incomes, can distort the results of the analysis. The research team found that in a study of land values, those closest to the expressway exhibited the largest gains between the early 1950's and mid-1960's and that there was no tendency to "shy away" from the expressway in terms of the construction of new residences.[8] In part, the greatest gain for properties located near the expressway resulted from an equalization of land values within the entire study area. Properties located near the expressway tended to have lower values than those more remote from the right-of-way before the construction of the expressway. An investigation of re-sales showed no noticeable difference in the behavior of property values one block from the expressway, compared with those three to five blocks away.

In addition to looking at the relationship between property values and noise levels, the research study made an inquiry of a group of realtors about their opinions of the

---

[6] United States Department of Transportation, Bureau of Public Roads, <u>Expressway Traffic Noise and Residential Properties</u>, July 1, 1967, a report prepared by David C. Colony, Assistant Professor, Department of Civil Engineering.

[7] <u>Ibid</u>., p. 4.

[8] <u>Ibid</u>., p. 58 and p. 60.

effect of freeway noise on property values. The questionnaire was not sent to a random sample of realtors. Rather, a questionnaire was sent to every second listing in the "yellow pages" under real estate. Of a total of 140 questionnaires, a usable response was received of about one-third. The survey sent to realtors was an opinion survey which revealed the "feelings" of those surveyed. The response to the questionnaire sent indicated that realtors believed that the freeway caused a considerable loss in property value (i.e., between 20 and 30 per cent). This questionnaire approach was a marked divergence from both the exacting scientific character of the study and data collected from other sources.

To confirm or negate both sets of collected data, objective and realtor survey, residents of the area were also surveyed. The sample consisted of those people living in close proximity to the expressway -- an area extending 1,100 to 1,200 feet from the right of way line of the expressway. According to the research group, the surveyed residents lived in an area where the noise levels were within an 80 to 85 decibel range. The results of the survey of property owners does not completely agree with data on property values. Fifty per cent of those responding said that noise was a disturbance.[9] Of those indicating that noise was a disturbance, about 40 per cent stated that the noise level was "very severe" and 63 per cent stated that they would not buy, build, or rent so close to an expressway again.[10] In this study, the results of the surveys to realtors and to home owners are consistent with one another but inconsistent with data on property values. It should be remembered that only 50 percent of those surveyed found noise to be a disturbance.

The results of the Toledo Study strongly suggest that if traffic noise, either real or anticipated, has a noticeable influence on the market value of residential property, it is for that property which is immediately adjacent to the expressway. In addition, the survey of residents found that at most the only steps taken to reduce outside noise were the installation of storm windows and keeping doors and windows closed.[11]

---

[9] Ibid., p. 137.

[10] Ibid., p. 137.

[11] The Toledo study suggests a narrow band of about 50 feet wide along the right of way line. Ibid., pp., 157-161.

Available data permit a rough estimate of the costs of abating ground transportation noise by relocation and by noise reduction at the source. In 1971, Wyle Laboratories estimated that approximately 420 square miles is subject to undesirable noise levels as a result of the nation's major urban freeway system.[12] Assuming the same nation-wide density pattern for land adjacent to major urban freeways, there are about 5,000 people per square mile or 2.1 million within the 420 square miles impacted by noise. Assuming that the land is valued, conservatively, at $10,000 per acre (including structures), the cost of noise easements would amount to about $2.68 billion (i.e., 268,000 acres at $10,000 per acre). The cost of relocation for about 500,000 families, using expenditure figures provided for under the Federal-Aid Highway Act of 1968 in the impacted area would amount to an additional $1.25 billion ($2,500 for each family). The combined costs of land acquisition and relocation would be about $3.93 billion in fiscal 1970, or approximately the same as total Federal spending for all federally supported community development and housing programs of $3.9 billion in fiscal 1971.

At present, data are not available on the costs to the producer and to the consumer, in the form of higher prices, for reducing motor vehicle-generated noise. A California State Highway Patrol Survey suggests that California State maximum noise limits can be reduced without placing a violation, or putting an undue economic burden, on those automobile owners who make reasonable efforts to maintain their automobiles, especially exhaust systems. Similar studies for other parts of the country should be made to determine the relationship between existing standards and noise levels and whether new standards are required. Data provided by studies that show how much noise should be reduced would, of course, be used as an input to estimates of changes in costs to producers and prices paid by consumers resulting from reduced noise levels. Testimony from the Chicago hearings suggests that an important reason for not incorporating noise-reduction devices is insufficient consumer demand at higher prices.[13] Unfortunately, even if quieter vehicles (new) were required, manufactured, and bought, there is no assurance that these vehicles would be maintained and would remain quiet. Additional costs would have to be incurred, such as those incurred to monitor, inspect, and enforce established

---

[12] Wyle Laboratory Report for EPA, "Community Noise, Transportation Noise, and Noise from Equipment Powered by Internal Combustion Engines," NTID 300-3, 1971.

[13] Chicago Hearings EPA, Preliminary Transcript, p. 237 and p. 238.

standards.[14]

Mitigating the impact from noise takes four principal forms: insulation of houses and buildings along freeways and busy streets, screening highways with trees or walls, land use planning for property bordering on heavily traveled roads, and easements.[15] The costs of insulating the receiver against ground transportation noise could be high compared with noise reduction at the sources. The least-cost method for insulating houses or buildings probably would be the installation of storm windows on the side of buildings along freeway corridors. The Toledo Study showed that although the public is aware of noise enamating from expressways, few people have taken any action to reduce the noise levels in their homes (less than 15 per cent of those surveyed). In the few cases where action was taken, it consisted mainly

---

[14] The Highway Research Board, National Research Council, sponsored research designed to predict noise levels expected from new highway facility construction. The research included a series of examples that lead to tentative noise design criteria or noise standards. One finding of the Highway Research Board's work is that there exists a strong relationship between highway noise and ambient noise in terms of expected community response and, therefore, the costs to reduce traffic noise. If highway noise is less than ambient noise, little or no community reaction can be expected in the form of demands for noise abatement. Highway noise in excess of 16 dB above the general ambient noise level is likely to result in widespread complaints and strong community action to reduce the traffic noise. Only sporadic complaints from those most sensitive to noise will occur when highway intrusion levels are less than 9 dB above the average ambient noise level. Highway noise in excess of 16 dB above the general ambient level is likely to result in widespread complaints and strong community action to reduce the traffic noise. If true, and if noise abatement controls are related to community pressure, the costs of freeway or expressway noise reduction might increase as ambient noise levels decrease.

Highway Research Board, National Research Council, National Academy of Sciences-National Academy of Engineering, National Cooperative Highway Design Guide for Highway Engineers, 1971, pp. 29-30.

[15] Melville C. Branch, R. Dale Beland, and Vern O. Knudsen, Outdoor Noise and the Metropolitan Environment: Case Study of Los Angeles with Special Reference to Aircraft, University of California, Los Angeles, 1970, pp. 10-11.

of keeping doors and windows shut or installing storm windows.[16] One measure of the social benefits of noise reduction is an estimate of the willingness of those affected by noise to incur expenses to reduce noise. At present, there is little evidence to indicate whether people adversely subjected to noise would spend money to reduce noise levels. Although an esthetic asset to most highways, there is debate whether landscape plantings do much to reduce noise. One estimate is that plantings would have to be 300 to 500 feet in depth to cut noise levels in half. Landscaping of this magnitude would be extremely costly.[17] It is believed that noise levels can be reduced by the use of "quiet" pavement surfaces and tires, but it is also believed that the trade-off for less noise might be adverse effects on safety.[18] A rough estimate of the cost of easements, including dislocation costs, is about $1.25 billion for 420 square miles of highway subject to undesirable noise levels in 1971. Land-use planning for busy highways and freeways, as well as for other aspects of urban development, is in a state of infancy.

Further research will give added insight about the costs and the benefits of noise abatement, including the allocation of such costs and benefits between producers and receivers. Some of the trade-offs for quieter highways might be: time, mileage, changing values of real estate, community dislocation, tax lease revenue, industrial development, and dislocation of negotiated distances by the motor carriers.

[16] David Colony, Op. Cit., p. 161.

[17] Chicago Hearings, Preliminary Transcript, p. 244.

[18] Ibid., p. 244.

Section V

The Economics of Noise Internal to the Residential Environment

In contrast to the noise from aircraft overhead or from nearby highways, which impinges on the residential dweller, is the noise generated within the household and by neighbors in day-to-day activities. Such activities include lawn mowing, dishwashing, vacuuming, and so forth.

5.1 The Cost of Noise in the Residential Environment

The noise generated by appliances and home equipment is pervasive and a part of every day living. So omnipresent are these noises that they are generally taken for granted or ignored. As was shown in the section on the growth of noise sources, however, the rapid proliferation of noise generators within and around the home and the concentration of population may raise noise levels and exposures to such an extent in the near future that a major noise problem will exist within the home itself.

Evidence indicates that there is little real danger of deafness or serious hearing damage resulting solely from products used within the home. The noisiest of products, e.g., disposals, lawnmowers, power saws and dishwashers are not used continuously. Thus, even though these products are quite noisy, the exposure time and frequency of exposure are not sufficient to cause serious hearing damage. Although the risk of hearing loss is not great at the present time, there is evidence that noise is a source of considerable annoyance within the household. Common sense, if not scientific evidence, reveals that noise can frustrate desires for rest, privacy, relaxation, and even sleep. Anyone who has been awakened by noise of a barking dog, or a loud party, is well aware of the irritation and annoyance involved.

It is difficult to place an accurate estimate on the cost associated with annoyance from noise. If the effects of noise were well known, and affected all individuals equally, the task would be considerably simplified. Such however, is not the case, for what some individuals (most people over 30 years of age) consider noise, other individuals (teenagers) consider "music to the ears" (rock music). Moreover, studies have shown that consciousness of noise is related to income levels. Table V-1 summarizes the results of a survey of individuals in Los Angeles, Boston, and New York that attempted to

Table V-1 Rank Ordering of Noise, by Source and Income Class: Los Angeles, Boston, and New York (Combined)

Source	All Incomes	Income Class High	Income Class Middle	Income Class Low
Traffic	10.0	10.0	10.0	9.8
Children/ Neighbors	6.9	5.0	6.2	10.0
Planes	2.3	3.2	2.7	.8
Industry	2.3	1.6	2.9	1.3
Other	1.9	.9	2.5	1.7
Animals	1.9	2.7	1.4	2.0
Sirens/Horns	1.7	2.1	1.7	1.4
Passersby	.9	.6	1.3	.6
Sonic Boom	.8	.3	1.4	.3
Motorcycles	.8	.8	1.0	.3
Trains	.5	.3	0.0	1.7

Source: "Noise in Urban and Suburban Areas," Op. Cit., p. 23

correlate consciousness of noise sources to income class.[1]

Not only does the annoyance of noise depend upon the source generating the noise and income group, but it has also been shown that people are more tolerant of their own noise than that produced by others.[2] Consider the data in Table V-2 derived from a study of apartment dwellers. With the single exception of the dishwasher, noises from other apartments were always more bothersome than the same type of noise from the apartment of the respondent. There is a human tendency to consider one's own noise as "necessary" and that produced by neighbors as unjustified, because it represents an invasion of acoustical privacy.

Studies have also shown that a major irritation associated with noise is sleep interference; the other most prevalent reasons for being bothered by noise are the "shock" of being startled, interference with activities such as watching TV or listening to radio, and the interruption of conversation. The results of a survey are shown in Table V-3. Given that the effects of noise depend upon the receiver, his socio-economic background, the noise source, and even the time of day (i.e., noise is much more annoying when a person is attempting to go to sleep or has been awakened), it is virtually impossible to predict an individual's reaction to a given sound stimulus without a considerable amount of ancillary information. Goldsmith and Jonsson have stated that:

> There are several different effects of or reactions to domestic noise. The primary effects are physical effects, possible symptoms or aggravation of disease, possible impairment of function, or interference with activities. Secondary to the physical reaction of perception may be feelings of annoyance, which are usually defined as the extent to which people report being bothered, disturbed or irritated. If a person's feelings of annoyance are strong enough they will lead him or her to try to modify the sound environment. They can also lead him to behave in a way which has social effects (i.e., create parent-child tensions, or moving of the

---

[1] U. S. Department of Housing and Urban Development, "Noise in Urban and Suburban Areas: Results of Field Studies," January, 1967, p. 22.

[2] Alexander Cohen, "Noise and Psychological State," Paper Presented at the National Conference on Noise as Public Health Hazard, June 13-14, 1968.

Table V-2 Per Cent of Apartment Occupants Finding Specified Indoor Noises Bothersome

Noise Source	From Adjacent or Upstairs Apartment	From Own Apartment
Plumbing	71.0	13.0
Garbage Disposal	73.1	32.0
Dishwasher	42.3	68.0
Doors Slamming	86.5	--
Walking	50.0	--
TV and Radio	7.0	--
Phone Ringing	1.0	--
Noises from Bedroom[a]	10.0	--
Talking in Halls, on Stairs, and Landing	17.0	--

[a]Conversation, baby crying, etc.

Source: Cohen, Op. Cit., p. 19.

Table V-3 Reasons Associated with Being "Very Bothered."

Source \ Reason	Wake Up	Keep from Going to Sleep	Startled	Interfere with Radio or TV	Interfere with Conversation	Shake or Vibrate the House	None
Children/ Neighbors	13	10	9	7	7	4	2
Traffic	6	9	3	7	4	3	2
Passersby	4	4	4	4	4	3	0
Others	3	3	2	2	1	2	0
Animals	6	3	2	0	1	0	0
Motorcycles	2	2	3	2	2	0	0
Industry	1	0	1	2	2	2	0
Sirens/Horns	2	0	1	2	1	0	0
Subways	1	1	1	1	1	1	0
Sonic Booms	0	0	1	0	1	0	0

Source: "Noise in Urban and Suburban Areas", Op. Cit., p. 25.

> residence). In addition to these physical or psychological reactions may be impairment of communication or of sleep.[3]

From the above, it is clear that there are a diverse set of possible reactions to noise. The social cost of noise within the home must be analyzed in terms of the economic consequences associated with the various effects of noise. A partial list of the effects of domestic noise is shown in Table V-4.

Even though it is possible to compile a partial list (Table V-4) of the possible effects of domestic noise, it is still difficult to attach an economic cost to these various effects. One of the reasons is that noise is likely to be a contributing factor rather than a direct cause of some of the effects listed. Consider the first item under "Symptoms of aggravation or disease," headaches. If all headaches were caused by noise then one measure of the cost of noise would be the amount spent on products to alleviate headaches. This approach, however, ignores the pain and anquish and the reduced effectiveness of the individual suffering from the headache and the economic consequences of the reduction in the ability to function. Further, headaches can be caused by any number of other factors. Moreover, some of the products used to combat headaches, aspirin for example, have a myriad of other medical uses. Two facts, however, can be postulated with certainty: noise can contribute to headaches, and can reduce the efficiency of an individual as well as his psychological well being.

Rather than attempt a rigorous assessment of the cost of annoyance caused by noise and the other varied effects, some plausible assumptions will be made which will permit a first order approximation of the economic consequences of domestic noise. To the extent that noise interferes with rest, relaxation, and sleep itself, domestic noise can be considered a source of fatigue. Further, if noise aggravates or contributes to headaches, muscle tension, anxiety, and so forth, it contributes to stress in the individual. An individual under stress who is also fatigued is unlikely to perform at his potential peak performance.[4] The quality and

---

[3] John R. Goldsmith and Erland Jonsson, "Effects of Noise on Health in the Residential and Urban Environment", Paper prepared for the American Public Health Association, August, 1969, (mimeographed), p. 8a.

[4] Goldsmith and Jonsson, Op. Cit., passium.

Table V-4 Possible Effects of Domestic Noise

Symptoms of Aggravation or Disease:	Headache Muscle Tension Anxiety Insomnia Fatigue Drug Consumption Other Reactions
Impairment of Functions:	Impairment of hearing, including temporary threshold shift and presbycusis
Interference with Activities:	Interference with --Relaxation and rest --Communication (Conversation, listening to radio, telephone and TV)
Feelings of Annoyance:	Fear Resentment Distraction Need to Concentrate
Individual Actions to Modify the Environment:	Installation of Air Conditioning so that windows can be closed. Installation of acoustic insulation materials to reduce noise in the home. Shutting windows. The use of masking noises, such as turning on the radio or TV or fan. Departure from environment.
Social Effects:	Concentration of lower social class families in noise pollutant residential areas. Spending less time at home because of noise problems. Withdrawl from communication Family tension.

Source: Goldsmith and Jonsson, Op. Cit., Table 1.

quantity of work (whether the work is domestic or related to a person's livelihood) are both apt to be lower under conditions of stress and fatigue. Neither a psychologist nor an industrial engineer is needed to prove that stress and fatigue adversely affect performance.

Therefore, it can be argued that domestic noise and the stress and fatigue associated with it affect the worker on the job. Not only might noise lower the quality and quantity of work, but it also seems plausible to assert that noise factors can diminish morale and contribute to absenteeism. These effects alone can have substantial economic consequences. If the Gross National Product is reduced by one per cent, due to the various effects of domestic noise, then, at present levels, domestic noise costs the economy nearly ten billion dollars of foregone output each year.

A tired and nervous person is obviously not as attentive or able to concentrate on the tasks that he is performing as a rested and relaxed person, i.e., noise can contribute to making a person more prone to accidents in both the home and the work environment.[5]

---

[5] The relationship between domestic noise and accidents within the home has just begun to receive attention by researchers. The following item appeared in The Washington Post of September 11, 1971, Section D, p. 43:

> If you have a habit of cutting yourself with sharp knives or if you are continually falling off the step-stool in the kitchen, it doesn't necessarily mean you are accident prone.
>
> It might be that your kitchen noise factor is too high, and in trying to escape, you injure yourself.
>
> This is an idea that is leading to a new study of design principles which might be identified as the psychobiology of design, says Professor Donald C. Hays of the University of Wisconsin. He is chairman of the Department of Environmental Design that has just made a study called The Auditory Environment in the Home.
>
> "In this study we were trying to correlate noise of products connected with tasks in the kitchen.... the extent to which startling effects may cause one suddenly to focus away from one's tasks. We have found kitchens are a deafening place for the housewife," Hay explained in an interview.
>
> If you can escape noises above 60 decibels and close the door, great. Or you might try wearing ear muffs. You won't notice an airplane at 60

[5] (Continued)

decibels if you are tuned to music.

Noises are decibel deceivers though. Whereas the ear-splitting knife sharpener registers in at only 80 decibels, the seemingly less noisy blender and wall-exhaust fan are likely to give off at 90 decibels--noise factors that might cause the skin to pale, the pupils to dilate and the adrenalin to increase, impairing work efficiency. The range vent fan registers in at 85, the garbage disposal at 80 and the dishwasher at a mere 70. A comforting thought might be that everything can be run at the same time without the decibel rate going appreciably above the highest noisemaker. It might be the clue to solving kitchen problems--turn everything on for one big blast, and go outdoors.

John Koss sponsored the university study on the auditory environment in the home to find out whether noise factors can be solved in future product design and whether home environment can begin to meet the needs of the family adjusting to it.

"There have been all sorts of studies on the effects of jet noises and factory noises, but no one has gotten in to the home areas," he explained.

The cost associated with accidents in the United States is an enormous sum, even if the pain and suffering of the individual and all indirect economic costs are ignored. Consider, for example, disabling injuries--defined as injuries resulting in the loss of one day's work. In 1968, the National Safety Council reported 2.2 million disabling injuries at work; it was estimated that the total time lost due to work injuries was about 245 million man-days.[6] If each individual were paid at an average of $2.50 per hour and worked an average of eight hours per day, then the total cost of accidents at work would be about $4.9 billion. If domestic noise had contributed substantially to as little as one per cent of these accidents because of stress and fatigue, then this component of the cost of domestic noise could be placed at $49.0 million. The National Safety Council has estimated the cost of accidents at the workspace in 1968 as $21.3 billion; given this amount, the plausible first approximation due to noise would be $213 million.[7]

[6] See Table A-7, Appendix.

[7] See Table A-8, Appendix.

There are numerous indirect economic costs associated with accidents and fatalities which can be briefly summarized. In addition to the loss of output, medical facilities, already in short supply, are further burdened by accident cases. If a significant reduction could be made in the accident rate by the abatement of domestic noise, considerable direct and indirect benefits would accrue to the economy as a whole. Rather than attempt to put a price tag on domestic noise, it seems more reasonable to approximate the total exposure of individuals to various domestic noise generators. Table V-5 presents an estimate of the total number of people exposed to noise generated from different kinds of appliances and tools.

It is evident that the exposure of individuals to noise in the home is substantial and, from the section on the growth in noise sources, it is also clear that domestic noise will be an increasing problem in the future.

5.2 The Economics of Domestic Noise Abatement

The two alternatives for the reduction of domestic noise are either to insulate the receiver from the source, or reduce the noise generated by the source itself. From a practical standpoint, the latter is the only viable alternative for noise generators used within the home. Insulating the receiver from the source would require the homemaker and other members of the family to don earmuffs or ear plugs when certain noisy products are operating. Such a proposal is patently absurd; the "cure" is worse than the disease. It can be suggested, however, that more sound insulation, of improved quality, in homes would reduce the annoyance from "neighbor-generated" noise.

Because of the heterogeneity of noise generators used within the home, it is not possible to obtain an estimate of the total cost of noise abatement programs. The one generalization that can be made, however, is that more money is required to produce a quieter product. The cost of quieting a particular product within a given time span can only be determined on a product-by-product basis. In response to letters sent to manufacturers who were promoting "quiet" as a design feature of some of their products, some estimates of the costs involved were obtained. Examples are cited below.

(1) The addition of a reed muffler to a chain saw decreased noise from 111 dB(A) to 101 dB(A) and (added) only 2 per cent to the cost of the chain saw package.

Table V-5 Individuals in the United States Exposed to Noise from Selected Appliances or Tools, 1970.

Appliance	Total Potential Exposure	Homemakers and Children Under Six Years of Age
	Millions	
Clothes Washer	183.0	50.1
Vacuum Cleaner	181.0	49.5
Clothes Dryer	80.3	22.0
Air Conditioner (Window & Central)	44.6	12.2
Dishwasher	47.1	12.9
Garbage Disposals	45.6	12.5
Food Mixer	163.0	44.5
Floor Polisher	31.9	8.7
Food Blender	63.1	17.1
Saws, Drills, etc.	39.8	11.9

Source: Bolt Beranek and Newman, Inc.

(2) A major producer of room air conditioners in 1966 produced a quiet unit that decreased noise levels inside a room by 15 per cent and outside the house by 10 per cent. Manufacturing costs rose 20 per cent.

(3) A manufacturer of garbage disposals states that an insulating "sound shell" can be placed around disposals to reduce noise at an additional cost of $2.00 per unit.

(4) A muffled pavement breaker has been developed that reduces noise 6 to 8 dB(A) without loss of efficiency. The retail price of the unit increased from $705 to $815--or by 15 per cent.

(5) A major manufacturer developed a "quiet" garbage truck chassis that raised the price only one per cent.

(6) Truck replacement mufflers that meet Society of Automotive Engineers standards cost between $58 to $80, while conventional mufflers cost $20-$30 less. Under normal use, a truck muffler wears out about once a year.

(7) A manufacturer of typewriters reports that sound-attenuating materials on electric typewriters adds only $0.60 to manufacturing costs.

(8) A silenced metal garbage can has been created that costs $1.80 more than a conventional model.

From the examples presented, it is evident that the cost of quieting the source varies substantially from a few cents or as little as one per cent of total cost to as much as twenty per cent of total cost. There are no generalizations that can be made about the cost of quieting a particular product. Until quite recently, few producers stressed or advertised "quiet" as one of the attributes of their products. Apparently, the consumer has not voiced a sufficient distaste for noise, perhaps regarding noise as the "price of progress" just as the belching smokestack at one time was the symbol of prosperity rather than air pollution.

5.3 Noise Internal to the Residential Environment: A Summary

There is ample evidence that millions of individuals are currently exposed to noise generated by products within and around the home. A plausible case can be made for asserting that a causal link exists between noise, stress, and fatigue, and accidents and fatalities. Without more extensive study and better data, however, it is impossible to estimate with much accuracy the economic costs of domestic noise. Accidents and fatalities are, however, expensive to both the individual and the economy. Efficiency in the workspace which affects productivity and also the quality of output are likely to be reduced from stress and fatigue resulting from noise at home. Even if noise is only indirectly responsible, a small percentage improvement in productivity could have large economic consequences. As a "ball park" estimate, therefore, it is reasonable to assert that the economic cost of domestic noise is in the billions of dollars.

At the present time, there appears to be no serious risk of hearing impairment or loss due solely to domestic noise. The economic cost of domestic noise is due to the annoyance produced. With the rapid growth in noise sources within the home, as shown in the section on the growth of noise generators, and with the growth in noise-density, due to increased population concentration, these annoyance effects and the associated economic costs are likely to increase dramatically in the near future. Case studies will be required to determine the cost of domestic noise abatement at the source. For some products, small expenditures have produced quieter products, but for others, manufacturing costs have been greatly increased to achieve noise reduction.

Section VI

Spending for Noise Abatement

6.1 Federal Expenditures

Although federal spending for noise-related activities has been growing slightly in recent years, the total for fiscal years 1968 through 1971 is estimated to be slightly more than $110 million. As Table VI-1 shows, between 60 and 70 per cent of total federal spending was made by the National Aeronautics and Space Administration, primarily for research and development activities for the Quiet Engine Program and for the Super-Sonic Transport (SST) Program.

An internal report of the Subcommittee on Noise of the Cabinet Committee on the Environment, chaired by the Secretary of Commerce, indicates that in fiscal year 1970 about 95 per cent of total federal spending was for noise related activities was directed toward problems associated with aircraft noise. The share going to aircraft noise was about 85 per cent of the total in fiscal year 1971. This means, of course, that in recent years only a small percentage of federal spending on noise-related programs has been directed toward highway, industrial, and other noise abatement programs. The Long Range Planning Service of the Stanford Research Institute forecasts that federal spending for aircraft noise abatement will decrease in relative importance as the Federal Government allocates more resources to reduce other sources of noise.

In contrast to spending for noise abatement, the Federal Government spent $163 million on air and $829 million on water pollution control and abatement activities in fiscal year 1970, according to the first annual report of the Council on Environmental Quality.

6.2 Private Spending

Although a few estimates have been made for individual programs, no estimate presently exists on the amounts private industry has spent for noise abatement problems in recent years.[1] For example, the Air Transport Association of America estimates that the airlines and aircraft manufacturers spent about $200 million for the development and

---

[1] An estimate of private spending for noise abatement would have to take into account a large number of diverse expenditures, some of which would include the following:

Table VI-1 Estimate of Federal Spending for Programs Related to Noise, Fiscal Years 1968 to 1971

Federal Agency	1968	1969	1970	1971	Total
NASA	--	21.6	24.7[c]	22.3	
Department of Transportation	10.0	3.2	5.3	8.9	103.3
Department of Defense[a]	--	2.1	2.7	2.5	
Health, Education, and Welfare	0.8	1.0	1.1	1.4	4.3
Department of Commerce	0.2	0.3	0.4	0.5	1.4
Housing and Urban Development	0.3	0.3	0.5	1.0	2.1
Department of the Interior	b	b	0.5	0.5	1.0
Total	11.3	28.5	35.2	37.1	112.1

[a]Primarily spending by the Air Force.

[b]Not available

[c]Includes $4.67 million for NASA Acoustics Facility

Sources: Data for 1968 and 1969 from Stanford Research Institute, Long Range Planning Service, Noise Pollution Control, Menlo Park, California, October 1970, p. 6. Data for 1970 and 1971 from Internal Document, Cabinet Committee on the Environment, Subcommittee on Noise, Secretary of Commerce, Maurice H. Stans, Chairman, 1970.

installation of noise suppressors for the first commercial jets.[2] Some other examples of the kind of information about private spending for noise reduction include the three following case studies: spending at a General Electric plant, at a paper mill, and at a manufacturing plant.

At a General Electric[3] plant in Evansdale, Ohio, there was a large office area adjacent to the factory. The advertising and product information employees who worked in the office were distracted by noises emanating from the factory, and complained about the 75 - 78 dB(A) ambient sound level in their office. The plant's industrial hygienist agreed that they had a legitimate complaint, and decided to re-suspend the ceiling, soundproof the doors, and acoustically treat the walls. The cost of these modifications was about $10,000, and management believes that they now have a happier, more creative advertising and product information department.[4]

Another industrial noise abatement project took place at an eastern paper mill which had installed a new wood

---

[1] (Continued)
1. Sales of acoustical tile and other sound absorbing materials (also the cost of other noise-abating construction techniques); 2. College or foundation or privately sponsored research on noise abatement; 3. The incremental costs to manufacturers to include the amount of noise-abating materials that they have incorporated into their products; 4. The incremental cost to New York City and to other cities to purchase partially silenced garbage trucks; 5. Sales of earplugs and earmuffs; 6. The costs of fleeing the urban environment that can be attributed to noise pollution; 7. The cost of piped music to mask other noises; and 8. The efforts of numerous citizen groups, some involving expensive lawsuits, to fight airport or traffic noise, or, to press for noise legislation and standards.

[2] Air Transport Association of America, A Fact Sheet on Aircraft Noise Abatement, January 20, 1970.

[3] Large Jet Engine Division (LJED) of G.E.

[4] Occupational Hazards, July 1968, pp. 33-36.

chipper to speed-up production.[5] The chipper cut logs into small chips and blew them from the chipper room into digesters through a system of pneumatic tubes. The operator who monitored this process was subject to noise levels of 114 dB(A), well above all hearing damage risk criteria. To solve this dilemma, a booth was constructed from which the operator could monitor the chipper (and incidentally be protected from flying chips). The amount spent for this action was around $2,500.

Case histories of industrial noise abatement costs can even be mildly humorous. The following quotation relates how a plant manager schemed to get money to enclose the noisy screw machine department.

> I arranged a stop on the Board of Directors' shop tour at the foremen's desks alongside the screw department. We used this stop to talk about what cost reduction drives had just done to cut manufacturing and inventory costs. They all had their hands cupped to their ears while I shouted at them with a straight face.
>
> At the next month's board meeting, the $8,000 authorization went through without a quibble as I expected.[6]

6.3 Patents as a Surrogate for Spending

An important output of research and development expenditure are patented inventions. The literature on research and development, as well as economic growth, reveals that patented inventions have been used as a measure of scientific and technological output. The principal justification for using patent activity as a measure of scientific progress is that patents pass a recognition or acceptability test (i.e., the examination in the Patent Office) for describing an invention that contributes something new. Because of the lack of available data on spending, patents are used here as a surrogate of input or expenditures rather than as a surrogate for output, i.e., the value of research and development expenditures.

---

[5] Science and Technology, October 1969, p. 38.

[6] Factory, November 1967.

The use of patented inventions as a measure of spending for noise-related problems is not precise for a number of reasons. First, there is no way to know whether the cost of an "average invention" remains the same over time. Second, there is no way to know whether the ratio of spending to inventions, and then the ratio of inventions to patents, in a given firm or sector of the economy, remains constant over time. Third, research indicates that there is a wide variation among business firms, and also among non-profit institutions and the Federal Government, to file patent applications on invention disclosures. Finally, it is impossible to identify patents issuing in any given year with R&D expenditures in some earlier year. Although a patent application usually pends for two and a half years in the Patent Office before issue (if it meets Patent Office criteria for patentability), some inventions are processed through the Patent Office more rapidly than others. Also, many patents cover inventions that are improvements on components of larger products and processes, with the R&D expenditure covering the entire product or process that is developed.

Despite these weaknesses, patents are the result of research and development effort and they must in some way mirror changes in levels of manpower and dollars going into a given area of research. In part, this reflects the fact that in early 1970, the Patent Office established a priority program for anti-pollution inventions. The Patent Office reports that a year after the inception of the program, 380 patent applications covering anti-pollution techniques and devices completed the Patent Office's examination and processing within eight months after application (as compared with the normal two and a half years). The accelerated process program has two important objectives. First, to increase the speed at which the inventions get into use by industry, and second, to make new information available to other inventors as soon as possible.[7]

Tables VI-2 and VI-3 present information about the growth in the numbers of patents issuing in Patent Office subclasses that relate to acoustics or to noise abatement devices. The relevant subclasses were selected by a Patent Office Examiner with many years of experience in the field of acoustics. The data in Table VI-2 give the number of

---

[7] "Patent Office Approves 380 Anti-Pollution Applications Under Priority Program," Commerce Today, March 8, 1971, Vol. I No. 2, p. 30. The Patent Office does not have a classification of these inventions by field, i.e., those covering air, water, solid waste, noise, etc.

Table VI-2 Number of United States Patents Issued In Patent Office Subclasses that Relate to Acoustics or Noise Abatement Devices, 1959 - 1970

Patent Office Class or Subclass

Year	Chemical[a]	Metal[b] Working	Buildings	Gas Separation[d]	Power Plants[e]	Acoustics[f]	Fluid Sprinkling, Spraying & Diffusing[g]	Total
1959	61	14	h	h	8	48	0	131
1960	29	28	h	h	6	69	0	132
1961	36	39	h	h	5	52	0	132
1962	36	31	h	1	24	44	0	136
1963	22	26	h	0	12	88	0	148
1964	38	21	h	1	8	58	0	126
1965	50	62	3	2	222	86	0	225
1966	35	53	8	3	24	61	0	184
1967	24	46	4	4	18	51	2	149
1968	20	45	5	3	24	58	0	155
1969	56	42	8	0	18	57	3	194
1970	46	34	3	4	22	72	2	183
Total	453	441	31	18	201	744	7	1,895

[a]Class 23 Subclasses: 284 (Chambers and Stacks) and 288 (Catalytic)
[b]Class 29 Subclass: 157 (Gas and Water)
[c]Class 52 Subclasses: 144, 145, 404, 405, 406, and 407
[d]Class 55 Subclass: 276 (Noise Attenuation)
[e]Class 60, Subclasses: 29 (Exhaust Treatment) and 30 (Fluid Mingling)
[f]Class 181, Subclasses: 30, and 33 through 72
[g]Class 239, Subclass: 265.13 (Reaction Mortar Discharge Nozzle) with Retractible Noise Suppressing Steam Divider
[h]No Issues

Sources: Compiled from data in United States Patent Office, Index of Patents, 1959-1969 and United States Patent Office, Official Gazette, 1970.

Table VI-3 Growth in United States Patents Issued in Patent Office Subclasses that Relate to Acoustics or Noise Abatement Devices, 1959 - 1970

Subclass	Growth in Number of Patents Per Year (Linear Regression)	Growth Rate in Percent Per Year (Logarthmic Regression)	Item 1959 - 1970
Chemical[a]	$y_2 = 605.38 + 29.95t$ $r^2 = .50$	$y_2 = 2.80 + .02x$ $r^2 = .48$	#23
Metal Working[b]	$y_2 = 462.44 + 68.45t$ $r^2 = .86$	$y_2 = 2.71 + .03x$ $r^2 = .88$	#29
Buildings[c]	$y_2 = 443.67 + 29.86t$ $r^2 = .11$	$y_2 = 2.57 + .04x$ $r^2 = .18$	#52*
Gas Separation[d]	$y_2 = 124.42 + 25.72t$ $r^2 = .74$	$y_2 = 2.12 + .05x$ $r^2 = .76$	#55**
Power Plants[e]	$y_2 = 620.95 + 7.76t$ $r^2 = .63$	$y_2 = 2.79 + .01x$ $r^2 = .58$	#60
Acoustics[f]	$y_2 = 111.35 + 4.51t$ $r^2 = .36$	$y_2 = 2.04 + .02x$ $r^2 = .42$	#181
Fluid Sprinkling, Spraying, and Diffusing[g]	$y_2 = 200.33 + 10.44t$ $r^2 = .41$	$y_2 = 2.30 + .02x$ $r^2 = .44$	#239***
All Subclasses Except 23	$y_2 = 83.38 + 5.65t$ $r^2 = .48$	$y_2 = 1.92 + .02x$ $r^2 = .53$	E Subclasses (except #23)
Mufflers and Sound Filters[h]	$y_2 = 17.03 + .10t$ $r^2 = .05$	$y_2 = 1.17 + .01x$ $r^2 = .13$	#33
All U. S. Patents Issued	$y_2 = 45862.95 + 1644.58t$ $r^2 = .50$	$y_2 = 4.67 + .01x$ $r^2 = .50$	Total All Patents Issued

Table VI-3 (Continued)

*From 1965-1971
**From 1962-1971
***1969 Eliminated

[a]Class 23, Subclasses: 284 (Chambers and Stacks) and 288 (Catalytic)
[b]Class 29, Subclass: 157 (Gas and Water)
[c]Class 52, Subclass: 144, 145, 404, 405, 406, and 407
[d]Class 55, Subclass: 276 (Noise Attenuation)
[e]Class 60, Subclasses: 29 (Exhaust treatment) and 30 (Fluid Mingling)
[f]Class 181, Subclasses: 30, and 33 through 72
[g]Class 239, Subclass: 265.13 (Reaction Mortar Discharge Nozzle) with Retractible Noise Suppressing Steam Divider
[h]No issues Subclass 33

<u>Key to Symbols</u>

- y = Growth, Growth Rate
- t = time (years)
- x = log t
- r^2 = coefficient of determination; statistical measure of the amount of variation in "y" explained by "t" or "x".

Source: Compiled from data in United States Patent Office, <u>Index of Patents</u>, 1959-1969, and United States Patent Office, <u>Official Gazette</u>, 1970 patents issued in seven broad fields (chemical, metal working, buildings, gas separation, power plants, acoustics and fluid sprinkling, spraying, and diffusing) between 1959 and 1970. It must be emphasized that these patents are Patent Office subclasses that are most likely to cover inventions that relate to noise abatement devices. Without examining each patent disclosure, it is impossible to know whether they do in fact.[8] The data in Table VI-3 give the average increase in the number of patents issued each year and the rate of growth in the number of patents that issue. All coefficients are positive, which means that the number of patents issued is increasing over time.[9]

The data in Table VI-3 show that all United States patents issued are growing at about 2.3 percent per annum. Patents relating to noise in Class 60 (Power Plants) are growing at about the same rate as are those in subclass 33 (Mufflers and sound filters) of Class 181 (Acoustics). The names of other subclasses in Class 181 are the following:

---

[8] Although each invention was not analyzed closely, the data collection process reviewed that class 29 (metal-working - subclass 157) and class 60 (Power Plants - subclasses 29 and 30) contained a large number of patents that covered devices for air pollution control relating to exhaust from different kinds of motors. It is believed that class 23 (subclasses 284 and 288 contained the largest number of inventions that did not relate explicitly to noise abatement and that class 181 (subclasses 30 and 33 through 72) contained the largest number of inventions relating to noise abatement.

[9] The low r^2's for a number of the items means that the fit of the equation is not good and the coefficient is not good for forecasting changes in the level of patenting activity in those classes. The purpose of this analysis is not to forecast changes in the numbers of patents in these subclasses. Moreover, with increased federal and private concern over noise-related problems, it is reasonable to assume that the numbers of inventions in these subclasses will increase more rapidly in the future. This is especially true if the Patent Office continues its Priority Program for Anti-Pollution inventions.

33 Mufflers and Sound Filters
34 Mouthpieces
35 Fluid conducting or guiding
36 Combined
37 With safety valve
38 with cut-out
39 Underwater exhaust
40 Manifold
41 Through passage
42 With sound absorbing material
43 With fluid mingling
44 With by-pass
45 Valve controlled
46 Multi-passage
47 Expansion chamber
48 Side branch chamber
49 Baffle type
50 With sound absorbing material
51 With fluid mingling
52 Liquid
53 Retroverted
54 With side branch chamber
55 Coaxial foraminous walls
56 Multi-passage
57 Expansion chamber
58 Centrifugal flow
59 Side branch chamber
60 Multiple outlet
61 Casings
62 Insulated
63 Baffle structure
64 Moving
65 Biased
66 Spiral
67 Helical
68 Perpendicular and oblique
69 Perpendicular
70 Oblique
71 Filling material
72 Accessories

Subclass 33 is the largest subclass in the acoustics area. Inventions in other subclasses that relate to acoustics or noise abatement devices are growing more rapidly than the number of total patents issued. For example, the relevant subclasses in chemicals; fluid sprinkling, spraying, and diffusing; and acoustics (except mufflers and sound filters) are growing at a rate of 4.7 per cent per annum. Noise related patents in metal working are growing at 7.2 per cent each year and those in the building class at about 9.6 per cent per annum.

Tables VI-4 and VI-5 show patenting activity for noise-related inventions from a different point of view - the ownership of inventions at time of issue. Although the stringency varies among the different Federal agencies and also among private business, both the Federal Government and private companies usually require inventors to assign titles to patents to the funding organization. The data in these tables reflect the relative amount of R&D on noise-related problems undertaken by the Federal Government, individuals, and business, during the past decade or so. Table VI-4 gives a percentage distribution for all relevant subclasses in seven broad patent office classes. Table VI-5 gives the number of patents, by assignee, in subclass 33 (Mufflers and sound filters) of Class 181 (acoustics).

The data displayed in both Table VI-4 and Table VI-5 strongly suggest that the private sector of the economy has been more active than the Federal Government in R&D on noise-related problems. During the entire 12-year period, the Federal Government acquired titles to less than five per cent, and in most years no more than two per cent, of all of the patents issuing in these subclasses. The same kind of distribution of patents between the Federal Government and private industry existed before World War II when the Federal R&D effort was just beginning to grow. Before World War II, universities, individuals, and private industry spent more for R&D than the Federal Government.

6.4 An Estimate of the Level of R&D Spending on Noise Abatement in the 1960's

In 1968, the National Bureau of Standards assisted in the preparation of a report for the Task Force on Noise of the Federal Council on Science and Technology.[10] The information developed tends to confirm patent statistics which show that most R&D on noise abatement was in the area of applied research and development and was undertaken by private industry. It was found that the Federal Government funded almost no research in the field of acoustics, apart from acoustical research associated with defense requirements. Based on a review of the Commerce Business Daily, the report identifies an expenditure of $259 thousand between 1963 and 1967 sponsored by the Federal Housing

[10] Internal Memorandum, from the National Bureau of Standards to the Members of the Federal Council on Science and Technology, Task Force on Noise, February 20, 1968.

Table VI-4 Percentage Distribution of United States Patents Issued in Patent Office Subclasses that Relate to Acoustics or Noise Abatement Devices, By Assignee 1959 - 1970

Year	Federal Government	Individual	Foreign	Large Business[a]	Other Business
1959	4	18	12	34	32
1960	1	27	10	33	29
1961	1	21	19	27	32
1962	0	25	13	31	31
1963	1	19	10	30	40
1964	1	16	13	45	25
1965	2	25	15	32	26
1966	1	20	10	32	37
1967	1	17	15	33	34
1968	2	17	16	30	35
1969	0	18	16	31	35
1970	1	14	27	29	29

[a]Among the *Fortune 500* in 1970

Sources: Compiled from data in United States Patent Office: *Index of Patents*, 1959 - 1969, and United States Patent Office, *Official Gazette*, 1970.

Table VI-5 Number of United States Patents Issued in Class 181 (Acoustics), Subclass 33 (Mufflers and Sound Filters), by Assignee, 1959 - 1970

Year	Federal Government	Individual	Foreign	Large Business[a]	Other Business	Total
1959	0	0	2	2	4	8
1960	1	6	2	3	2	14
1961	1	4	2	6	6	19
1962	0	6	3	5	4	18
1963	0	3	4	9	22	38
1964	0	1	2	9	5	17
1965	0	3	2	5	9	19
1966	0	5	3	5	5	18
1967	0	2	1	3	6	12
1968	1	1	2	3	2	9
1969	0	1	3	8	4	16
1970	1	4	6	5	5	21
Total	4	36	32	63	74	209

[a]Among the *Fortune 500* in 1970.

Sources: Compiled from data in United States Patent Office, *Index of Patents*, 1959 - 1969, and United States Patent Office, *Official Gazette*, 1970.

Administration.[11] The report also lists two contracts of an undetermined cost for noise reduction in hospitals funded by the Public Health Service between 1963 and 1967.[12] The report estimated that in the late 1960's, the national effort of the United States on noise pollution and its abatement was so far below that of the Canadian Government that the United States would have to accelerate its research effort by "one hundred fold" to match the then existing Canadian program on a per capita basis.[13] Although the report probably neglected to account for a number of studies because of the complicated nature of Government R&D procurement, it does strongly suggest that the Federal Government did not have a positive program in the area of noise pollution and its abatement in the late 1960's.

6.5 Research Efforts of Associations

One way to find out about research conducted in the private sector of the economy is to ask associations about their activities and the activities of their members in the area of noise and its abatement. Many, if not most, national associations have representatives located in Washington, D. C. In August 1971, telephone calls were made to approximately 80 associations in the Washington metropolitan area that could be interested in problems associated with noise. Whenever possible, the calls were made to directors of research or to librarians. The associations included representatives of industrial, labor, and consumer groups. Of the 80 associations called, about 30 stated that they were interested in the matter of noise and its abatement; and 13 organizations provided information about their research efforts. Initially, it was hoped that the associations could estimate the amounts of money spent on noise related research; unfortunately this was not possible.

Table VI-6 lists the names of those organizations that provided information about their research efforts. The table also indicates the kinds of research sponsored or undertaken by the Associations. The research efforts of these

---

[11] The Commerce Business Daily, is a publication of the Federal Government that lists contract proposals and also contracts awarded by the Federal Government.

[12] Internal Memorandum from NBS to FCST, p. 18.

[13] Ibid., p. 16

Table VI-6 Research Activities of Selected Associations Concerned with Noise Abatement

Association	Comments on Kind of Research
Aerospace Industries Association of America	Conducts and sponsors research and disseminates research conducted by others.
American Automobile Association	Collects and disseminates information gathered by others.
American Highway Users Association	Conducts research and disseminates research undertaken by others.
American Speech and Hearing Association	Collects research of others, principal interest is effects of noise on receivers.
American Trucking Association	Sponsors research, emphasis on research on noise reduction at the source
Airport Operators Council International	Sponsors research and disseminates research of others, emphasis on importance of Federal R&D to reduce noise at source.
Air Transport Association of America	Conducts research and disseminates research of others.
Forest Industries Council	Collects and disseminates research undertaken by others.
National Association of Air Traffic Specialists	Collects and disseminates research of others.
National League of Cities and U. S. Conference of Mayors	Sponsors research and disseminates research of others, emphasis of research on a "Model Noise Ordinance" for cities.
National Machine Tool Builders Association	Collects research of others, principal emphasis on measurement techniques.

Table VI-6 (Continued)

Association	Comments on Kind of Research
National Safety Council	Conducts research and disseminates research results of others. Forces of research on measurement and effects on receiver.
Sierra Club	Collects research of others.

associations include: (1) the conduct of research, (2) sponsoring research, and (3) data collection and dissemination. The comments listed in the table do not distinguish between the magnitudes of research undertaken by these organizations. Some of the research conducted by these associations consisted of rather short reports, whereas the research of other organizations were sizeable projects that could have cost in excess of $100,000.

Although no conclusions can be drawn about R&D expenditures, based on the activities of associations in the private sector, the telephone survey strongly suggests that a growing number of organizations are becoming concerned about noise-related problems. With only one or two exceptions, the research conducted or sponsored by these organizations is of recent origin - most of which was undertaken between 1969 and 1971.

6.6 Spending for Noise Abatement: A Summary

In part, the lack of empirical information required for an economic appraisal of the costs of noise and its abatement is reflected by the fact that spending for noise research during the last 10 years has been small. In addition, most of the research that has been undertaken has been applied research and developmental engineering conducted by private industry. Although it is tautologous, it is important to emphasize that without research and data, it is impossible to know the cost of noise to society. And, without knowing the cost of noise, it is not possible to estimate either the benefits that will accrue to society from various levels of abatement, nor is it possible to estimate the costs of abatement to producers and to consumers in the form of higher prices.

Section VII

Summary and Conclusions

From the foregoing analysis, several general conclusions can be obtained. First, it is apparent that aircraft noise is presently a major problem with substantial economic costs. Secondly, because of the lack of data on noise levels and an inadequate understanding of the effects of noise, it is difficult to assess the cost of noise within the home or from nearby highways and freeways. Thirdly, if the trends in growth in noise generators and in urban/suburban population concentrations continue, noise could become a much more serious problem in the near future. Finally, practical as well as economic considerations suggest that it is generally preferable to attempt to abate noise at the source, rather than insulate the noise receiver.

Industrial noise has already been recognized as a major problem by the Department of Labor's regulations promulgated under the Occupational Safety and Health Act of 1970. The data on the relationship between noise levels, productivity, accidents, and employee morale and turnover are fragmentary at best. It is plausible to assert that noise in the industrial environment does influence the quantity and quality of output as well as labor turnover costs. The economic impact of these considerations could be substantial, but research is required before quantification of the economic cost of industrial noise is possible.

Compared to research on air and water pollution, research on the economics of noise is in a state of infancy. For example, in 1968, the Federal Water Pollution Control Administration began a complete assessment of waste treatment facilities for all population served by sewers in the United States. Most states have made estimates of the amounts of money that might be required to clean up the nation's rivers and streams, but almost no effort has been undertaken in the area of noise.

Because it is neither technologically feasible nor economical currently to manufacture a totally quiet jet engine, a combination of retrofitting jet engines, providing a noise right of way around airports, and insulating homes will be necessary to achieve an acoustically acceptable living environment around major airports. Therefore research should be directed toward a "Land Use Planning Policy" which provides for noise rights of way between airports or major highways and freeways and the residential environment.

Moreover, noise from jet aircraft should be considered in conjunction with the air pollution problem caused by the jet, and an "integrated" attempt at solving both problems simultaneously should be made. In short, noise should not be viewed as a separate problem when other forms of pollution were also present. The same reasoning should be applied to other noise sources as well, e.g., highway vehicles.

An analysis is required of the economic trade-offs between the benefits derived by communities from highways and the costs of the associated noise. Freeways provide access to areas which could influence the relocation of industry and regional growth rates. Such benefits, however, must be weighed against the cost of highway noise abatement and the cost of the noise itself.

Studies should be made to determine the economic impact of noise standards for products. The economic consequences of noise abatement on prices, GNP, employment, etc., will depend upon the "time frame" in which the abatement is effected. "Crash programs" requiring immediate compliance could produce significant price increases and have an adverse effect on employment, foreign trade, and productivity. The gradual "phasing in" of such standards, however, could avoid some of these consequences. Thus, research efforts should be devoted to consideration of the time requirement on abatement regulations, the impact on manufacturers and on prices paid by the consumer.

Another important area of further research is an analysis of the effects that noise standards have on the competitive position of United States products in foreign countries. The combined effect of all environmental quality standards on changes in costs of production and therefore price should be appraised in view of the chronic balance of payments deficit witnesses by the United States during the past decade. The principle research effort should concentrate on changes in the relative prices of United States goods in world markets resulting from the cost of compliance to environmental quality standards versus possible reductions in imports into the United States because of foreign noncompliance with United States standards.[1]

[1]There is, of course, the converse problem in that U. S. exports may not meet foreign noise standards. This is also worthy of further research.

Research efforts should also be directed toward the investigation of the economic effects of noise on property values. Studies of property values in noise areas versus control properties in "quiet" areas are required to remove the ambiguity in the results obtained from such efforts to date. Particular attention to the resale values and turnover rates of noise affected properties will aid an economic impact evaluation of noise in the residential environment.

Research on the economic cost of industrial noise should focus on the effects of noise on factors which influence the quality and quantity of output. The effect of noise on worker attitudes and accident rates must also be investigated in order to understand the economic implications of industrial noise. Such efforts will have to attempt to quantify the relationship between noise levels and accident rates, worker productivity, and lower turnover.

Another important area of research is an estimate of the economic costs and benefits of alternative means of measuring noise and alternative methods of enforcing allowable noise standards. The cost and the effectiveness of various noise measurement instruments are likely to cover the wide spectrum from inexpensive and not very effective to inexpensive and sufficiently effective, and from expensive and sufficiently effective to expensive and super-effective. It is obvious that if noise abatement standards are not enforced, the established norms would become meaningless. Again, there is an economic trade-off between the levels and means of enforcing standards and the benefits derived from those different enforcement techniques.

APPENDIX A

CONTENTS

APPENDIX A CONTENTS (Cont'd)

Table A-1 Airport Operations by Year and Type at All Airports with FAA Towers, 1957 - 1968

Year	Total	Air Carrier	General Aviation	Military	Number of FAA Towers
1957	25,149,667	7,112,208	12,128,625	5,908,834	205
1958	26,593,337	6,997,079	14,032,448	5,563,810	215
1959	26,905,856	7,352,849	15,008,103	4,544,904	222
1960	25,773,990	7,164,394	14,826,063	3,783,533	229
1961	26,300,767	6,980,246	15,527,863	3,792,658	254
1962	28,200,570	7,059,630	17,367,249	3,773,691	270
1963	30,976,773	7,339,533	19,921,053	3,716,187	277
1964	34,194,659	7,447,434	23,019,865	3,727,360	278
1965	37,870,535	7,819,114	26,572,650	3,478,771	292
1966	44,952,816	8,206,322	33,445,126	3,301,368	304
1967	49,886,840	9,359,960	37,222,622	3,304,258	313
1968	55,292,035	10,377,089	41,564,024	3,350,922	322

Source: Federal Aviation Administration

Table A-2 Noise Sources: Growth in Selected Series Related to Surface Transportation Noise, Selected Years, 1950 - 1970.

Item	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year Logarithmic Regression
Automobile, Bus & Motorcycle Miles of Travel	Statistical Abstract of United States	Millions of Miles	$Y = 548526 + 28897t$ $r^2 = .980$	$Y = 5.746 + .018x$ $r^2 = .984$
Truck Miles of Travel	Statistical Abstract of United States	Millions of Miles	$Y = 120427 + 8192.7t$ $r^2 = .981$	$Y = 5.091 + 022x$ $r^2 = .966$
Value of New Construction	Statistical Abstract of United States	Million of Dollars, 1957-59 Prices	$Y = 52465 + 1306.1t$ $r^2 = .862$	$Y = 4.720 +.010x$ $r^2 = .881$
Value of New Highway and Street Construction	Statistical Abstract of United States	Millions of Dollars, 1957-59 Prices	$Y = 6115.32 + 140.59t$ $r^2 = .562$	$Y = 3.784 + .010x$ $r^2 = .586$
Total Motor Vehicle Registration	Bureau of Public Roads, Federal Housing Administration, Department of Transportation	Number in Millions	$Y = 69.93 + 3.43t$ $r^2 = .998$	$Y = 1.833 + .017x$ $r^2 = .996$
Automobile Registration	Bureau of Public Roads, FHA, DOT	Number in Millions	$Y = 55.78 + 2.75t$ $r^2 = .996$	$Y = 1.753 + .017x$ $r^2 = .996$
Truck or Bus Registration	Bureau of Public Roads, FHA, DOT	Number in Millions	$Y = 10.87 + .62t$ $r^2 = .985$	$Y = 1.05 + .018x$ $r^2 = .992$

Table A-2 (Continued)

Item	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year Logarithmic Regression
Motorcycle Registrations	Statistical Abstract of United States	Thousands of Units	$Y = 353.37 + 192.53t$ $r^2 = .988$	$Y = 2.718 + .068x$ $r^2 = .974$

Table A-3 Vehicle Miles of Travel in the United States
(Millions)
Selected Years, 1940 - 1968

Year	Autos, Buses, Motorcycles	Truck	Total
1940	252,257	49,931	302,188
1945	204,232	45,941	250,173
1950	367,694	90,552	458,246
1955	492,047	111,387	603,434
1960	592,436	126,409	718,845
1963	649,854	155,569	805,423
1964	682,229	164,271	846,500
1965	716,376	171,436	887,812
1966	756,592	173,905	930,497
1967	779,097	182,456	961,553
1968	819,000	196,650	1,015,650

Source: United States Department of Transportation.

Table A-4 Value of New Construction Put in Place (Millions of 1957 - 1959 Dollars), Selected Years, 1950 - 1969

Year	Highway and Street Construction	Type of Construction Private	Public	Total
1950	$2,722	$34,309	$ 9,267	$43,576
1955	4,396	38,394	13,323	51,717
1960	5,758	36,518	15,653	52,171
1963	6,998	40,308	17,793	58,101
1964	7,003	40,861	18,311	59,172
1965	7,108	43,780	19,116	62,896
1966	7,365	43,208	19,733	62,941
1967	7,269	40,967	20,177	61,144
1968	7,565	43,775	20,657	64,432
1969	6,886	44,911	19,258	64,169

Source: Statistical Abstract of the United States

Table A-5 Motor Vehicle Registration (Millions), Selected Years, 1950 - 1975[b]

	Vehicle Type		
Year	Automobiles	Trucks and Busses	Motorcycles
1950	40.3	8.8	.45
1955	52.1	10.6	a
1959	59.4	11.9	a
1960	61.7	12.2	.570
1961	63.4	12.6	a
1962	66.1	13.1	a
1963	69.0	13.7	a
1964	71.9	14.3	a
1965	75.3	15.1	1.38
1966	78.1	15.9	1.75
1967	80.4	16.5	1.95
1968	83.7	17.3	2.10
1969[b]	86.6	18.1	2.26
1970[b]	89.0	18.7	a
1971[b]	91.4	19.2	a
1972[b]	93.7	19.7	a
1973[b]	95.9	20.2	a
1974[b]	98.0	20.7	a
1975[b]	100.1	21.2	a

[a]Not Available

[b]Automobile, Truck, and Bus Registrations are estimates by the Bureau of Public Roads

Source: U. S. Department of Transportation

Table A-6 Noise Sources: Growth in Selected Types of Home Appliances, 1959 - 1970.

Item	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Automatic Washers	Association of Home Appliance Manufacturers	Number in Thousands	$Y_2 = 2541.68 + 142.20t$ $r^2 = .842$	$Y_2 = 3.416 + .018x$ $r^2 = .822$
Window Air Conditioners	Association of Home Appliance Manufacturers	Number in Thousands	$Y = 429.14 + 406.36t$ $r^2 = .908$	$Y = 3.059 + .058x$ $r^2 = .938$
Power Lawn Mowers	Outdoor Power Equipment Institute, Inc.	Number in Thousands	$Y = 3328.03 + 184.79t$ $r^2 = .826$	$Y = 3.534 + .018x$ $r^2 = .815$
Central Air Conditioning Units	Air Conditioning and Refrigeration Institute	Number in Thousands	$Y_2 = 18.121 + 126.58t$ $r^2 = .946$	$Y = 2.401 + .070x$ $r^2 = .990$
Garbage Disposers	Association of Home Appliance Manufacturers	Number in Thousands	$Y = 519.94 + 117.54t$ $r^2 = .944$	$Y_2 = 2.819 + .041x$ $r^2 = .952$
Dishwashers	Association of Home Appliance Manufacturers	Number in Thousands	$Y_2 = 252.62 + 176.43t$ $r^2 = .979$	$Y = 2.686 + .064x$ $r^2 = .980$

Table A-7 Disabling Injuries by Source of Injury (000's), 1959 - 1970

Year	Motor Vehicle	Work	Source of Injury: Home	Source of Injury: Public	Total
1970	2,000	2,200	4,000	2,700	10,800
1969	a	a	a	a	a
1968	2,000	2,200	4,300	2,600	11,000
1967	1,900	2,200	4,300	2,500	10,800
1966	1,900	2,200	4,400	2,400	10,800
1965	1,800	2,100	4,200	2,400	10,400
1964	1,700	2,050	4,300	2,250	10,200
1963	1,600	2,000	4,400	2,200	10,100
1962	1,500	2,000	4,300	2,100	9,800
1961	1,400	1,900	4,000	2,100	9,300
1960	1,400	1,950	4,100	2,050	9,400
1959	1,400	1,950	3,900	2,050	9,200

[a]Not Available

Source: National Safety Council.

Table A-8 National Accident Fatality Toll, by Source of Accident, 1959 - 1970

Year	Motor Vehicle	Work	Home	Public	Total
		Source of Accident			
1959	37,800	13,800	26,000	16,500	91,000
1960	38,200	13,800	27,500	16,500	93,000
1961	38,000	13,500	26,500	16,500	91,500
1962	40,900	13,700	28,500	17,000	97,000
1963	43,600	14,200	29,000	17,500	101,000
1964	47,700	14,200	28,500	18,000	105,000
1965	49,000	14,100	28,000	19,000	107,000
1966	53,000	14,500	29,500	19,500	113,000
1967	53,100	14,200	28,500	20,000	112,000
1968	55,200	14,300	28,500	20,500	115,000
1969	56,400	14,200	27,000	21,000	115,000
1970	54,800	14,200	26,500	22,000	114,000

Source: National Safety Council

Table A-9 Estimated Lost Time and Cost of Accidents, 1959 - 1970

Year	Time Lost Due to Work Injuries (Millions of Man Days)	Cost of Accidents (Billions of Dollars)
1959	230.0	13.0
1960	230.0	13.6
1961	230.0	14.5
1962	235.0	15.5
1963	230.0	16.1
1964	235.0	16.7
1965	235.0	18.0
1966	255.0	20.0
1967	245.0	21.3
1968	245.0	22.7
1969	250.0	a
1970	250.0	a

[a]Not Available

Source: National Safety Council.

Table A-10 Deaths from Accidents in Selected Industries, 1959 - 1970.

Industry	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Construction	National Safety Council	Number	$Y_2 = 2311.7 + 45.96t$ $r^2 = .767$	$Y_2 = 3.365 + .008x$ $r^2 = .741$
Trade	National Safety Council	Number	$Y_2 = 1184 + 6.23t$ $r^2 = .283$	$Y_2 = 3.074 + .002x$ $r^2 = .352$
Manufacturing	National Safety Council	Number	$Y_2 = 1783 + 1.39t$ $r^2 = .0035$	$Y_2 = 3.253 + .0003x$ $r^2 = .002$
Mining, Quarrying, Oil and Gas Wells	National Safety Council	Number	$Y_2 = 766.54 - 13.91t$ $r^2 = .643$	$Y = 2.883 - .007x$ $r^2 = .483$
Agriculture	National Safety Council	Number	$Y_2 = 3565.7 - 89.71t$ $r^2 = .900$	$Y_2 = 3.557 - .013x$ $r^2 = .851$
Transportation and Public Utilities	National Safety Council	Number	$Y_2 = 1553 + 18.75t$ $r^2 = .474$	$Y_2 = 3.192 + .005x$ $r^2 = .463$
Service Industry	National Safety Council	Number	$Y = 1730 + 78.57t$ $r^2 = .991$	$Y = 3.245 + .016x$ $r^2 = .994$
Government	National Safety Council	Number	$Y = 1475 + 46.79t$ $r^2 = .866$	$Y = 3.170 + .013x$ $r^2 = .964$

Table A-11 Disabling Injuries from Accidents in Selected Industries, 1959 - 1970.

Industry	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Construction	National Safety Council	Number in Thousands	$Y = 192.07 + 4.51t$ $r^2 = .904$	$Y = 2.284 + .009x$ $r^2 = .904$
Trade	National Safety Council	Number in Thousands	$Y = 359.67 + 3.86t$ $r^2 = .438$	$Y = 2.56 + .004x$ $r^2 = .446$
Manufacturing	National Safety Council	Number in Thousands	$Y = 363.32 + 10.05t$ $r^2 = .770$	$Y = 2.563 + .010x$ $r^2 = .769$
Mining, Quarrying, Oil and Gas Wells	National Safety Council	Number in Thousands	$Y = 47.55 - .49t$ $r^2 = .132$	$Y = 1.675 - .005x$ $r^2 = .131$
Agriculture	National Safety Council	Number in Thousands	$Y = 310.4 - 8.43t$ $r^2 = .925$	$Y = 2.501 - .015x$ $r^2 = .898$
Transportation and Public Utilities	National Safety Council	Number in Thousands	$Y = 184.2 + 1.54t$ $r^2 = .632$	$Y = 2.268 + .003x$ $r^2 = .632$
Service Industry	National Safety Council	Number in Thousands	$Y = 315 + 16.43t$ $r^2 = .994$	$Y = 2.500 + .02x$ $r^2 = 1.00$
Government	National Safety Council	Number in Thousands	$Y = 265 + 9.29t$ $r^2 = .862$	$Y = 2.42 + .016x$ $r^2 = .910$

Table A-12 Factors Affecting Productivity and the Level of Output, 1960 - 1970.

Item	Source	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Cost of Accidents	National Safety Council	Millions of Dollars	Y = 11247 + 1072t r^2 = .969	Y = 4.079 + .026x r^2 = .962
Deaths at Work from Accidents	National Safety Council	Number	Y = 13674 + 59.09t r^2 = .537	Y = 4.136 + .002x r^2 = .529
Disabling Injuries at Work from Accidents	National Safety Council	Number	Y = 1877.7 + 31.28t r^2 = .867	Y = 3.275 + .007x r^2 = .866
Time Lost due to Work Injury	National Safety Council	Millions of Man-Days	Y = 224.99 + 2.165t r^2 = .697	Y = 2.353 + .004x r^2 = .697
Deaths at Home from Accidents	National Safety Council	Number	Y = 27469 + 55.94t r^2 = .032	Y = 4.438 + .001x r^2 = .033
Disabling Injuries at Home from Accidents	National Safety Council	Number	Y = 4099.2 + 16.54t r^2 = .110	Y = 3.612 + .002x r^2 = .110
Hypertension Rate in United States	Statistical Abstract of United States	Deaths Per 100,000	Y = 65.287 - 1.916t r^2 = .992	Y = 1.82 - .018x r^2 = .994
Hearing Aid Units Sold	National Hearing Aid Journal	Number	Y = 336130 + 19354t r^2 = .924	Y = 5.535 + .02x r^2 = .923

Table A-13 Sales of Selected Noise Generating Home Products (000's), 1959 - 1970

Year	Garbage Disposals	Dishwashers	Product Automatic Washers	Air Conditioning Room	Air Conditioning Central	Power Lawn Mowers
1959	789	a	2,934	1,660	307	4,200
1960	760	555	2,562	1,580	350	3,800
1961	800	620	2,668	1,500	366	3,500
1962	890	720	2,975	1,580	468	4,000
1963	1,090	880	3,296	1,945	580	3,900
1964	1,300	1,050	3,541	2,725	702	4,100
1965	1,355	1,290	3,771	2,960	826	4,500
1966	1,410	1,528	3,890	3,345	959	4,900
1967	1,356	1,586	3,878	4,129	1,047	4,900
1968	1,738	1,960	4,140	4,026	1,235	5,200
1969	1,943	2,118	4,068	5,459	1,635	5,700
1970	1,976	2,116	3,869	5,887	1,616	5,650

[a]Not Available

Sources: Association of Home Appliance Manufacturers, Outdoor Power Equipment Institute, Inc., and Airconditioning and Refrigeration Institute.

Table A-14 Sales of Hearing Aids
1963 - 1970

Year	Number of Units
1963	363,379
1964	387,449
1965	393,531
1966	400,207
1967	410,573
1968	448,895
1969	470,981
1970	510,747

Source: National Hearing Aid Journal.

Table A-15 Noise Sources: Number of Production Workers in Selected Industries, 1959 - 1966.

Industry	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Mining	Number in Thousands	$Y = 588.4 - 14.7t$ $r^2 = .86$	$Y = 2.77 - .01x$ $r^2 = .88$
General Building Contractors	Number in Thousands	$Y = 755.2 + 12.4t$ $r^2 = .34$	$Y = 2.88 + .01x$ $r^2 = .39$
Heavy Construction Contractors	Number in Thousands	$Y = 489.4 + 9.1t$ $r^2 = .72$	$Y = 2.69 + .01x$ $r^2 = .72$
Lumber and Wood Products	Number in Thousands	$Y = 567.4 - 6.0t$ $r^2 = .36$	$Y = 2.75 - .004x$ $r^2 = .239$
Primary Metal Industries	Number in Thousands	$Y = 902.3 + 19.2t$ $r^2 = .54$	$Y = 2.96 + .01x$ $r^2 = .51$
Fabricated Metal Products	Number in Thousands	$Y = 795.6 + 24.9t$ $r^2 = .68$	$Y = 2.91 + .01x$ $r^2 = .72$
Textile Mill Products	Number in Thousands	$Y = 827.4 - 1.0t$ $r^2 = .01$	$Y = 2.9171 - .0005x$ $r^2 = .009$
Railroad Transportation (All Employees)	Number in Thousands	$Y = 929.1 - 28.6t$ $r^2 = .940$	$Y = 297 - .02x$ $r^2 = .921$
Local and Inter-Urban Passenger Transit (All Employees)	Number in Thousands	$Y = 283.6 - 2.3t$ $r^2 = .756$	$Y = 2.451 - .003x$ $r^2 = .737$

Table A-15 (Continued)

Industry	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Trucking and Warehousing (All Employees)	Number in Thousands	$Y = 799.8 + 23.0t$ $r^2 = .902$	$Y = 2.91 + .01x$ $r^2 = .921$
Transportation by Air (All Employees)	Number in Thousands	$Y = 168.1 + 8.6t$ $r^2 = .902$	$Y = 2.23 + .02x$ $r^2 = .940$
Metal Stamping (All Employees)	Number in Thousands	$Y = 138.4 + 5.4t$ $r^2 = .640$	$Y = 2.14 + .02x$ $r^2 = .672$
Paper and Allied Products	Number in Thousands	$Y = 464.3 + 5.4t$ $r^2 = .810$	$Y = 2.66 + .01x$ $r^2 = .864$
Printing and Publishing	Number in Thousands	$Y = 563.7 + 8.5t$ $r^2 = .774$	$Y = 2.75 + .01x$ $r^2 = .792$

Source: Bureau of Labor Statistics.

Table A-16 Estimated Number of Selected Types of Earthmoving Equipment, 1960 - 1970.

Year	Crawler Tractors	Crawler Loaders	Wheel Tractors	Wheel Loaders	Scrapers	Rollers	Graders	Totals
1960	7,442	5,027	1,193	3,742	1,588	2,692	3,016	24,700
1961	6,413	3,309	1,318	3,632	1,258	3,085	2,645	21,660
1962	7,907	3,980	1,487	4,058	1,758	2,841	3,264	25,295
1963	9,926	5,456	1,816	5,394	3,159	3,214	4,118	33,083
1964	11,406	5,823	2,421	7,900	4,044	4,107	4,526	40,227
1965	14,277	6,876	3,176	8,650	4,714	2,771	4,545	45,009
1966	17,251	6,949	4,306	9,695	4,912	2,777	4,827	50,717
1967	12,704	5,066	2,330	8,935	3,459	4,645	4,939	42,078
1968	13,747	6,214	1,424	10,856	3,249	5,191	4,962	45,643
1969	13,983	6,999	3,693	12,519	3,357	5,552	5,042	51,145
1970	19,538	7,570	3,749	12,787	3,699	7,009	5,440	59,792
Total	134,594	63,269	26,913	88,168	35,197	43,884	47,324	439,349

Source: Associated Equipment Distributors.

Table A-17 Noise Sources: Growth in Selected Types of Earthmoving Equipment, 1960 - 1970.

Item	Units	Growth in Number of Units Per Year (Linear Regression)	Growth Rate in Per Cent Per Year (Logarithmic Regression)
Crawler Tractors	Number of Machines	$Y = 5707.76 + 1088.01t$ $r^2 = .767$	$Y = 3.813 + .040x$ $r^2 = .839$
Crawler Loaders	Number of Machines	$Y = 3868.65 + 313.85$ $r^2 = .603$	$Y = 3.596 + .025x$ $r^2 = .568$
Wheel Tractors	Number of Machines	$Y = 1082.78 + 227.31t$ $r^2 = .456$	$Y = 2.903 + .124x$ $r^2 = .887$
Wheel Loaders	Number of Machines	$Y = 2012.87 + 1000.4t$ $r^2 = .956$	$Y = 3.500 + .061x$ $r^2 = .925$
Scrapers	Number of Machines	$Y = 1841.98 + 226.29t$ $r^2 = .381$	$Y = 3.223 + .041x$ $r^2 = .478$
Rollers	Number of Machines	$Y = 1805.73 + 363.96t$ $r^2 = .700$	$Y = 3.356 + .037x$ $r^2 = .688$
Graders	Number of Machines	$Y = 2734.27 + 261.32t$ $r^2 = .876$	$Y = 3.452 + .029x$ $r^2 = .826$

Source: Associated Equipment Distributors

BIBLIOGRAPHY

Acceptability Criteria Symposium, Transportation Noise, Proceedings, University of Washington, Press, 1970.

Air Transport Association of America, A Fact Sheet on Aircraft Noise Abatement, January 20, 1970.

Atlanta Hearings, Preliminary Hearings.

Aylesworth, Thomas G., This Vital Air, This Vital Water, Rand. 1968.

Aylor, Donald E., "Plants Filter Noise," Horticulture, February 1971, Volume XLVIX, No. 2, p. 28.

Baron, Charles I., "Noise" AMA Journal, March 1, 1971, Volume 215, No. 9, p. 1399

Beranek, Leo L., Noise Reduction, McGraw-Hill, 1960.

Baron, Robert A., The Tyranny of Noise, St. Martin, 1970.

Berland, Theodore, Fight for Quiet, Parry-Hill, 1970.

Berland, Theodore, "The Maddening Pollutant," Let's Live, Volume 39, No. 1, January 1971, p. 77.

Bird, David, "Rickles Asks Noise Limits to Ban All Jets from City," New York Times, December 31, 1970, p. 48.

Bolt Beranek and Newman, Inc., "A Study -- Insulating Houses from Aircraft Noise," United States Department of Housing and Urban Development, Federal Housing Administration, 1966.

Bolt Beranek and Newman Report for EPA, "Noise from Construction Equipment, and Operations, Building Equipment and Home Appliances," NTID 300-1, 1971.

Bragdon, C. R., Noise Pollution: The Unquiet Crisis, University of Pennsylvania Press, October 1971.

Branch, Melville C., and Beland, R. Dale, and Knudsen, Vern O., Outdoor Noise and the Metropolitan Environment: Case Study of Los Angeles with Special Reference to Aircraft, University of California, Los Angeles, 1970, pp. 10-11.

Burns, William, Noise and Man, Lippencott, 1969.

Chicago Hearings EPA, Preliminary Transcript.

Cohen, Alexander, "Noise and Psychological State," Paper presented at the National Conference on Noise as a Public Health Hazard, June 13-14, 1968.

Colony, David C., "Expressway Traffic Noise and the Residential Properties," 1967, United States Department of Transportation, Bureau of Public Roads.

"Concorde Spurs Basic Research in Noise," Aviation Week and Space Technology, February 8, 1971, Volume 94, No. 6, p. 74 - 78.

Department of the California Highway Patrol, Passenger Car Noise Survey, Sacramento, California, January, 1970, (mimeographed).

Dygert, Paul K., "On Measuring the Cost of Noise from Subsonic Aircraft," The Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, 1970.

Factory, November, 1967.

Goldsmith, John R. and Erland Jonsson, "Effect of Noise on Health in the Residential and Urban Environment," paper prepared for the American Public Health Association, August, 1969, (mimeographed).

Harmik, Peter, "Machine Music Drills the Ear," Environmental Action, Volume 2, No. 15, December 12, 1970, p. 3.

Harris, C. M., Handbook of Noise Control, McGraw-Hill, 1957.

Hienonymous, Will S., "New Landing Method Aimed at Reduction in Approach Noise," Aviation Week and Space Technology, March 1, 1971, Volume 94, No. 9, p. 46.

Highway Research Board, National Research Council, National Academy of Sciences--National Academy of Engineers, National Cooperative Highway Design Guide for Highway Engineers, 1971, pp. 29-30.

House Interstate and Foreign Commerce Committee, Hearings on Noise Pollution Abatement Act, H. R. 923, January 22, 1971.

Joint DOT-NASA Civil Aviation Research and Development Policy Study, Supporting Papers, March, 1971, DOT TST-10-5, NASA SP-266.

Judd, Sebastian F. et. al, "Detachable Elastomer Muffler for Pneumatic Percussive Tools," Patent No. 3, 554, 316, filed November 25, 1969, Chicago Pneumatic Tool Co., New York, New York, Official Gazette, January 12, 1971.

Judd, Stanley H. and Spence, John H., "Noise Control for Electric Motors," Society of Safety Engineers Journal, January 1971, Volume 16, No. 1, p. 25-31.

McClure, Paul T., "Indicators of the Effect of Jet Noise on the Value of Real Estate," Rand Corporation, Santa Monica, California, July, 1969, pp. 24ff.

"More Power, Less Noise at the Twist of a Blade," New Scientist, December 17, 1970, Volume 48, No. 730, p. 505.

Mulholland, Kenneth, "Predicting the Noise of Airports," New Scientist and Science Journal, March 18, 1971, Volume 49, No. 743, p. 604-07.

National Academy of Sciences, "Jamaica Bay and Kennedy Airport: A Multidisciplinary Environmental Study," 1971, Volume II, pp. 95-96.

National Aeronautics and Space Administration, "NASA Acoustically Treated Nacelle Program," 1969, pp. 63-73 and pp. 109-117.

National Hearing Aid Journal.

Navarra, John G., Our Noisy World: The Problem of Noise Pollution, Doubleday, 1969.

"Noise Pollution: Trees Act as Buffer," Science News, January 1, 1971, Volume 99, No. 1, p. 15.

Occupational Hazards, July, 1968.

"Patents Office Approves 380 Anti-Pollution Applications Under Priority Program," Commerce Today, March 8, 1971, Volume 1, No. 2, p. 30.

Pickard, Jerome P., "Dimensions of Metropolitorism" Research Monograph 14, Urban Land Institute, 1967, p. 47.

"Pollution Control Equipment: Noise Pollution," Industrial Equipment News, January 1971, Volume 38, No. 1, p. 32.

Poulands, Richard O., "Model Studies in Acoustics," Office of Naval Research, London, NTIS AS-716 950, December 7, 1970, research report.

Science and Technology, October, 1969.

Stanford Research Institute, Long Range Planning Service, Noise Pollution Control, Menlo Park, California, 1970, p. 6.

Statistical Abstract of the United States, 1970.

Scott, David, "Diesel Noise Cut," Automotive Industries, January 1, 1971, Volume 144, No. 1, pp. 35-38.

Seebold, James E., "Noise Controlled at Design Stage," Oil and Gas Journal, Volume 68, No. 51, December 21, 1970, pp. 56-59.

Slatick, Eugene R., "Noise!" Pennsylvania Game News, April 1971, Volume 42, No. 4, pp. 14-17.

Still, Henry, In Quest of Quiet, Stackpole, 1970.

Taylor, R., Noise, Pelican Paperback, 1971.

Towne and Associates, Inc., The Robin M., An Investigation of the Effect of Freeway Traffic Noise on Apartment Rents. A report prepared for the Oregon State Highway Commission and the United States Department of Commerce, Bureau of Public Roads, October 1966.

U. S. Department of Commerce, Internal Document, Cabinet Committee on the Environment, Subcommittee on Noise, Secretary of Commerce, Maurice H. Stands, Chairman, 1970.

U. S. Department of Commerce, The Noise Around Us, September 1970.

U. S. Department of Housing and Urban Development, "Noise in Urban and Suburban Areas: Results of Field Studies," January, 1967, pp. 22-23.

United States Patent Office, Index of Patents, 1959-1969

United States Patent Office, Official Gazette, 1970.

U. S. Department of Transportation, Federal Aviation Administration, Statistical Handbook, 1969.

U. S. Department of Transportation, Federal Aviation Administration, Statistical Handbook, 1970.

Wedgewood, Anthony, "Rolls Royce and the Environment," A Member of Parliament Writing in New Scientist and Science Journal, February 11, 1971, Volume 49, No. 738, p. 296.

Woolsey, James P., "Airport Operators Push Engine Retrofits," Aviation Week and Space Technology, March 1, 1971, Volume 94, No. 9, p. 46-48.

Wyle Laboratory Report for EPA, "Community Noise, Transportation Noise, and Noise from Equipment Powered by Internal Combustion Engines," NTID 300-3, 1971.