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REPORT TO CONGRESS

STUDY – THE FEASIBILITY, PRACTICABILITY AND COST OF THE SOUNDPROOFING OF SCHOOLS, HOSPITALS, AND PUBLIC HEALTH FACILITIES LOCATED NEAR AIRPORTS

Required by Section 26 (3), Appendix B of
The Airport and Airway Development Act
Amendments of 1976 (Public Law 94-353)

DEPARTMENT OF TRANSPORTATION
UNITED STATES OF AMERICA

JULY 1977

U.S. DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

JUL 14 1977

Honorable Walter F. Mondale
President of the Senate
Washington, D.C. 20510

Dear Mr. President:

I am pleased to transmit to you the enclosed study entitled "The Feasibility, Practicability and Cost of the Soundproofing of Schools, Hospitals, and Public Health Facilities Located Near Airports." This study is required by Section 26(3), Appendix B of the Airport and Airway Development Act Amendments of 1976 (Public Law 94-353).

As a result of this effort, I have concluded that the soundproofing of schools, hospitals, and public health facilities is feasible and practicable. The Department of Transportation will be considering what further actions may be appropriate to promote this type of noise alleviation.

Sincerely,

Brock Adams

Brock Adams

Enclosure

THE SECRETARY OF TRANSPORTATION
WASHINGTON, D.C. 20590

JUL 14 1977

Honorable Thomas P. O'Neill, Jr.
Speaker of the House of Representatives
Washington, D.C. 20515

Dear Mr. Speaker:

I am pleased to transmit to you the enclosed study entitled "The Feasibility, Practicability and Cost of the Soundproofing of Schools, Hospitals, and Public Health Facilities Located Near Airports." This study is required by Section 26(3), Appendix B of the Airport and Airway Development Act Amendments of 1976 (Public Law 94-353).

As a result of this effort, I have concluded that the soundproofing of schools, hospitals, and public health facilities is feasible and practicable. The Department of Transportation will be considering what further actions may be appropriate to promote this type of noise alleviation.

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DIGEST

Section 26(3) of the Airport and Airways Development Act Amendments of 1976 (P. L. 94-353) requires the Secretary of Transportation to report to the Congress with respect to the feasibility, practicability, and cost of soundproofing noise-impacted schools, hospitals, and public health facilities, in order to reduce the possible adverse effects of aircraft noise. This report fulfills that requirement.

There is no known direct health effect (e.g., hearing loss) on the occupants of public buildings due to aircraft noise in the United States. Aircraft noise does interfere with speech communications in affected schools, and with sleeping or resting in affected hospitals and public health facilities.

A survey of the impact of aircraft noise on 60 school and hospital buildings was conducted near six major U.S. airports within Noise Exposure Forecast (NEF) 30 areas to acquire a representative sample of aircraft noise impact on such buildings nationwide. These types of public buildings provide roughly a 20 decibel (dB) reduction of exterior noise levels, so that interior noise from outside sources is perceived to be approximately one-quarter as loud as that same noise just outside each building (each 10 dB reduction corresponds to a halving of the perceived loudness). For example, an aircraft flyover producing an A-weighted sound level of 90 dB outside a school building would produce a level of 70 dB inside the classrooms of that building. This level of noise is sufficient to interfere with spoken communication between teachers and their students, and thus interrupt classroom instruction. Improved noise reduction requires building modifications, to increase the sound attenuation of the walls and ceilings. It was found that certain building modifications could be grouped into categories which provide the same order of improvement in sound attenuation. Category A modifications, providing a 10 dB improvement, primarily consist of replacing existing windows with sealed double glazing, and installing weatherstripping and insulation. Category B modifications, providing a 20 dB improvement, include eliminating windows and sealing those areas with existing wall materials. Mechanical ventilation is included in either category.

Building modifications for noise reduction purposes were estimated for the sample of 60 buildings surveyed as part of this study. Resultant noise reductions and costs provided a basis for extrapolation to all such buildings within a NEF 30 impact area around airports nationwide.

The nationwide cost estimate for rehabilitation of noise-impacted public and private schools, hospitals and public health facilities near airports is shown in the following table together with the number of noise-impacted occupants in these buildings.

Item	Schools	Hospitals*
Buildings	1,100	90
Occupants	707,000	31,000
Rehabilitation Cost	$148,000,000	$56,000,000

*Includes Public Health Facilities

The rehabilitation costs are those necessary to achieve feasible and practicable limits of soundproofing. While not as accurate as a case-by-case application, these modifications reduce the total number of students impacted within the study (above an ambient A-weighted sound level of 55 dB) from 84.0 to less than 10.0 percent, and the total number of patients impacted (above an ambient A-weighted sound level of 50 dB) from 97.5 to 21.0 percent. Reduced levels of rehabilitation might be preferable to those levels of improvement evaluated within the study. These determinations should be made, however, on a case-by-case basis.

As a result of the two categories of rehabilitation assumed in the study for schools, hospitals and public health facilities, it is estimated that annually for schools, an average of at least $3.3 million worth of teaching time can be recovered and $1.78 million worth of energy costs can be saved. For hospitals and public health facilities, the energy savings are estimated at $.25 million. Additionally, benefits attributed to reduced patient care time are indicated although this benefit has not been estimated.

CHAPTER 1

INTRODUCTION

Public Law 94-353,* enacted July 12, 1976, requires that the Secretary of Transportation conduct a study to assess "the feasibility, practicability, and cost of the soundproofing of schools, hospitals, and public health facilities located near airports." In conducting the study, the Secretary was to consult with and solicit the views of such planning agencies, airport sponsors, other public agencies, airport users, and other interested persons or groups as deemed appropriate.

The Secretary was further required to report the study results to Congress within one year of the date of enactment of Public Law 94-353 and to include legislative recommendations, if any, developed as a result of the study.

The findings and results of this report are based on a study conducted and associated efforts undertaken by the Office of Environmental Quality of the Federal Aviation Administration (FAA).

Subsequent to the passage of Public Law 94-353, the Department of Transportation (DOT)/FAA has developed a comprehensive Aviation Noise Abatement Policy statement (November 18, 1976), which stresses the need for vigorous preventative and corrective measures to minimize the impact of aviation noise. Moreover, the DOT/FAA policy recognizes that those efforts cannot be successfully concentrated upon the airplane alone. Action complementary to the quieting of the noise source (the aircraft engine) such as effective land use planning must also be encouraged. The soundproofing of existing buildings is certainly consistent with that policy subject only to the constraints of feasibility, practicability and cost. In addition, recent amendments to the Federal-aid highway statutes permit Federal expenditures for the purpose of noise attenuation. Soundproofing of public, and in some cases private structures on a case-by-case basis is proceeding under this authority.

The study program established to fulfill the legislative requirements included consultation with recognized experts in the field of acoustics and psychoacoustics; discussions with officials having jurisdiction in the schools, hospitals and public health facilities under consideration; and actual field visitation at a representative sampling of building sites to gather data from which determinations of costs and benefits would be derived. To assist in completing the technical aspects, the field

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* Section 26(3), Appendix B of the Airport and Airway Development Act Amendments of 1976.

investigations, and the statistical impact and costing analysis of this study program, a contract was established with the Trans Systems Corporation, Vienna, Virginia, in conjunction with Wyle Laboratories, El Segundo, California. This report is based in large part on the results of that contractual effort. The document (DOT/FAA-AEQ-77-9) containing the contractual data compiled is available upon request.

This report is presented in a sequence which parallels the actual study program development. First, the study data had to be obtained. This exercise is detailed in Chapter 2 and contains a discussion of such related major items as determining the noise-impacted areas; the numbers and regions of the field tests required in order to develop accurate data for use in national level projections; the methodology through which field noise measurements would be taken; and the instrumentation necessary for acquiring meaningful data.

The magnitude and determination of the noise impact on schools, hospitals and public health facilities around airports were developed next and are discussed in Chapter 3. This part of the work stemmed directly from the field investigations and measurements taken.

Chapter 4 details those corrective engineering and construction techniques determined to be applicable in rehabilitating buildings impacted by airport-related noise in order to lower interior noise levels.

The determination of costs related to the rehabilitation of airport noise-impacted buildings is contained in Chapter 5 and is presented on a national level. Varying regional construction and material costs were taken into consideration in addressing this aspect of the work.

Chapter 6 discusses the benefits that could be achieved through the soundproofing of public buildings and defines those benefits considered to be most significant.

A determination of the feasibility and practicability of such soundproofing is, in reality, a reflection of Chapters 4, 5 and 6 (Rehabilitation, Costs and Benefits, respectively) and is treated in Chapter 7.

Chapter 8 describes the type and extent of consultations and coordination undertaken at the various stages of the soundproofing study program and is followed by a summary chapter (number 9) which reiterates the basic findings of the entire study.

Apart from the study's objectives, but of direct interest, it is worth noting that activity on soundproofing of public buildings is proceeding at several locations as a result of local litigation. In Seattle, the operator of the Seattle-Tacoma Airport is being required to pay the cost of soundproofing several schools. This requirement arose out of litigation which culminated in an opinion by the Washington Supreme Court. In Highline School District v Port of Seattle, 87 Wash 2d 6, 548 P.2d 1085 (1976), the Court held that where a governmental unit is obligated to furnish service which requires use of property, just compensation may be measured by the cost of providing necessary replacement facilities or the cost of modifications necessary to continue the obligatory use.

In a similar matter, the soundproofing of between 30 and 35 schools near Los Angeles Airport is taking place under a consent decree. In Los Angeles Unified School v The City of Los Angeles, Los Angeles Superior Court No. 965067 (1976), the parties agreed to exchange $20.9 million for a noise easement on 63 schools in five school districts. The City of Los Angeles has filed a pre-application with FAA for funds, through the Airport Development Aid Program, to assist in this work. FAA is currently assessing this project to determine its possible eligibility under existing statutory authority.

CHAPTER 2

DATA ACQUISITION

DETERMINATION OF NOISE IMPACTED AREAS

Investigation of buildings located "near airports" (as defined in Public Law 94-353) first required a functional definition of an area around airports impacted by aircraft noise. The buildings considered in the study would then be those within such an impacted area.

The area of noise impact surrounding an airport varies as a function of the aircraft type and number of operations to and from the airport. The soundproofing study used a common impact assessment approach for all airport-community areas considered. The selected approach is known as the Noise Exposure Forecast (NEF) methodology, with NEF 30 designating the impact area. While several metrics exist for defining noise exposure around airports, NEF 30 is recognized and understood as an exposure level above which community concern mounts. Therefore, for this study, the schools, hospitals and public health facilities identified as being noise impacted are those located within NEF 30 contours. Exceptions to this impact criterion were made where a local authority identified a specific site, outside NEF 30, as noise sensitive.

FIELD INVESTIGATIONS

At the outset it was evident that a representative but limited number of on-site investigations had to be made of schools, hospitals and public health facilities around airports. The on-site sampling was necessarily limited by funding and time constraints.

Six different regions within the continental United States were established as sampling regions. The basis for the determination of sampling regions included climatic conditions, availability of building materials and labor, type of seismic zone, local construction trends, and local economic conditions. Figure 1 shows the geographical separation of these divisions. A brief description of each region with its qualifying conditions follows:

--Region A: The Pacific Coastline. The climate is relatively mild as far inland as the Sierra Nevada foothills. This area contains three major metropolitan sections. The population concentration is relatively high, bringing with it the influx of skilled trades. Lumber is plentiful as are aggregates for concrete, and most other standard building materials. The high economic level of a metropolitan and industrial area permits use of more expensive methods and materials for aesthetic purposes. Seismicity for this area is high and is an important consideration.

--Region B: Inland Southern California, Southern Nevada, and Southwestern Arizona. Climate of hot, dry summers and relatively mild winters. Closely spaced metropolitan areas do not exist. Lumber is imported, but sand and aggregates for concrete block are plentiful. Therefore, in this area buildings will have a greater percentage of concrete masonry. Concrete block structures are cool in the long summers. The common stud-and-stucco combination is also popular, as maintenance is low in comparison to wood which requires more frequent painting.

--Region C: The Gulf Coast and South Atlantic Coastline. This area has a relatively mild climate with high humidity and is subject to violent tropical storms. Clay for brick is readily available as is local lumber. Brick and concrete block construction is popular. When wood framing is used, it is often protected by brick veneer. Because of the high humidity and generous rainfall, concrete block is often protected by exterior plaster.

--Region D: Eastern Seaboard and Inland to Central Illinois. The climate is quite cold for half the year and insulation properties are important. Brick, clay and local lumber are available, and the labor availability in all trades is generally good.

--Region E: Great Lakes (Western) States and Central South. Although these areas have considerably different climates, the average construction is similar due to economics. Lumber is local and plentiful, as is clay for brick.

--Region F: Central States. These areas are governed more by economics than by climate. All parts of this area experience below-freezing winters and hot, moderately humid summers. More important, however, is the commonality that, with the exception of very localized spots such as the Seattle-Tacoma area, urbanization and industrialization are not concentrated; consequently, the economy of the area is the prime factor, and materials and construction combinations giving best insulation at least cost are dominant.

On-site field investigations were conducted at a major hub airport-community within each of the six regions. The airport-communities investigated were:

--Region A: Los Angeles, California.

--Region B: Phoenix, Arizona.

--Region C: Miami, Florida.

--Region D: Boston, Massachusetts.

--Region E: Atlanta, Georgia.

--Region F: Denver, Colorado.

Geographical Areas of Differing Construction Practices

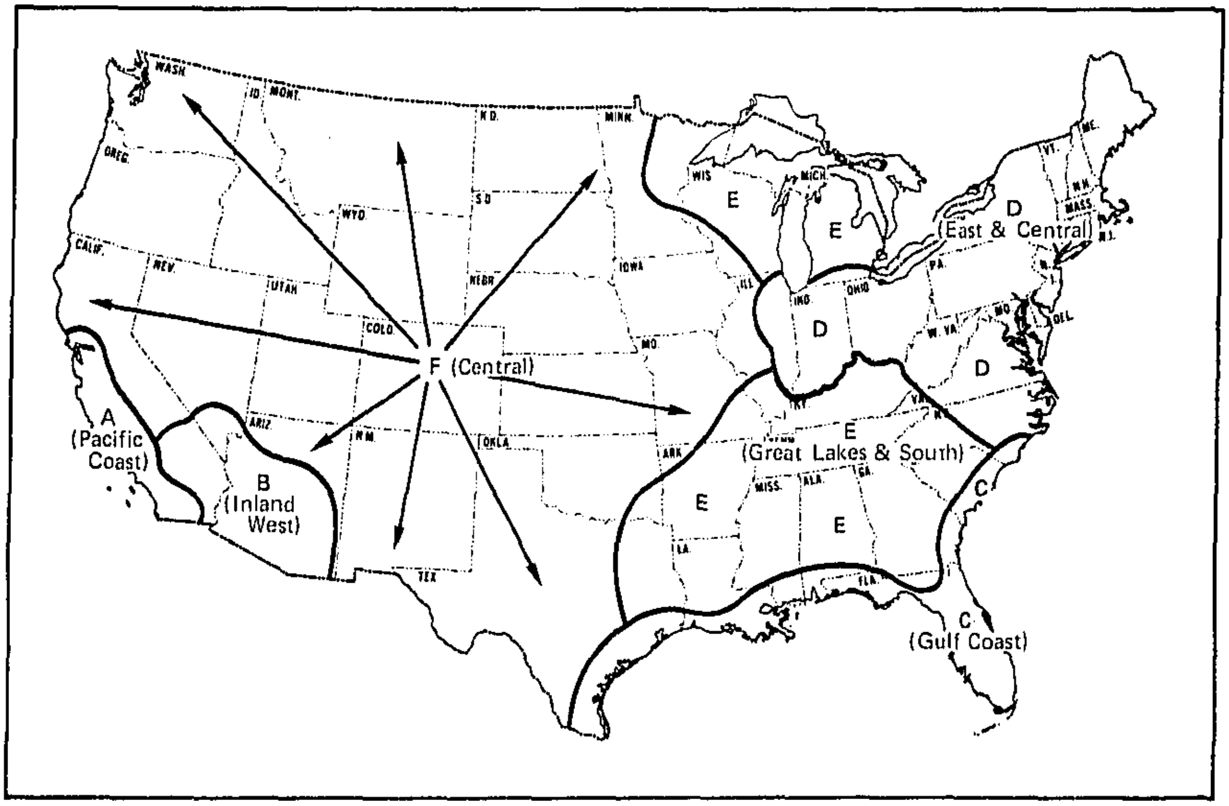


Figure 1

Within the noise impacted area surrounding each airport, ten buildings (schools and/or hospitals) were selected for detailed study. Selection of buildings was based on a cross-section of building types in concert with the following criteria.

--Building design and construction.

--Age.

--Size.

--Proximity to airport.

--Exposure to noise environment.

Data were obtained on building construction, size, use, occupancy and other pertinent aspects from visual inspection and direct measurement, or by examination of detail building plans when available. Work sheets were used to record these data and the actual data obtained were used in the analysis and costing portion of the study.

An investigation was made of local building locations and conditions including available plans and specifications, based on the same criteria and required information as that of on-site investigations, at all other large and medium hub airport-communities across the nation. Data were obtained by direct contact with local authorities. This process was successfully completed by telephone and/or the mails.

Forty random samples of small general aviation airport-communities supporting jet operation were also taken. On a regional basis these airports were grouped under the FAA National System of Airport Classification (1972 National Airport System Plan). Using alternative stratum procedures, the data obtained were projected to estimate the impact at the remaining small airports within each region.

The data obtained through these procedures provided nationwide statistics compiled from regional data which includes numbers of buildings and occupants, location, size, construction, materials, age, and other pertinent factors necessary to analyze and assess the effects and need for soundproofing.

NOISE MEASUREMENTS

Exterior and interior noise levels were measured during aircraft flyovers at selected locations within three geographical regions. The objectives of these field measurements were to:

--Provide direct base data on the attenuation properties of building types subject to the study.

--Provide measured noise levels for comparison and validation of a prediction methodology used in determining building noise reduction capabilities.

With the assistance of local authorities, buildings were selected within the noise impacted area of a large hub airport in each of three geographical regions. Regions were selected to reflect the diversification in climate, construction patterns and local conditions throughout the country. The regional areas and airport-cities selected, were:

--Region A: Los Angeles, California.

--Region D: Boston, Massachusetts.

--Region F: Denver, Colorado.

Ten buildings within each area were considered for noise measurements. Minor deviations resulting from adverse weather, local flight patterns and certain other uncontrollable on-site conditions slightly altered these measurements at selected sites. However, the measurements taken were sufficient in number and accuracy to satisfy study requirements.

INSTRUMENTATION

The instrumentation system used in taking the measurements consisted of a two-channel magnetic tape recorder equipped with two condenser microphones. A precision sound level meter was used for direct reading of sound levels, and also as an amplifier in one microphone channel. The frequency response of each channel of the assembled system was tested. The system response was found to be flat to within ±1 dB over a frequency range of 100 to 8000 Hertz (Hz). In the field, 1000 Hz calibration tones were recorded before each set of measurements. Standard practices and procedures, including calibration, were used in taking of all measurements.

MEASUREMENT DATA

Table 1 shows the noise measurement data taken in the Los Angeles area. Similar measurements were taken of buildings in the Boston and Denver area. The values shown represent the simultaneously measured exterior and interior noise levels and the differences between the two, which is the existing building/room noise reduction (NR) capability. All values are maximum A-weighted sound levels expressed in decibels. Except as noted, each value shown is the arithmetic average of measurements from twelve noise events. The deviations of the exterior and interior levels are due primarily to variation of levels among individual aircraft. The deviations of the resultant noise reductions are due to variations associated with different aircraft spectra, together with specific room characteristics. These variations are normally expected, and are the reason noise reduction is taken as the average of a number of events and a number of interior positions.

Table 1

Measured Levels and Noise Reduction-LAX

Building	Room	Exterior Max. (db)	Exterior Std. Dev. (db)	Interior Max. (db)	Interior Std. Dev. (db)	Avg. NR (db)	Avg. NR Std. Dev. (db)
Imperial School	2	85.7	4.1	56.8	3.2	28.9	1.8
	11	85.0	5.2	57.5	3.1	27.5	2.6
	6	82.6	5.1	50.8	3.4	31.8	2.5
Lennox H.S.	4 Bldg 3	71.3	3.3	50.9	4.2	20.4	2.3
	3 Bldg 6	75.6	5.6	53.7	5.7	21.9	2.0
	3 Bldg 4	71.3	3.7	57.9	3.3	13.4	1.5
Felton Ave. School	9	89.1	5.0	70.8	5.6	18.3	2.4
	5	83.8	6.5	65.7	8.7	18.1	2.7
	11	86.1	6.0	66.9	7.3	19.2	2.4
Clyde Woodworth School	4	78.4	5.1	57.0	4.1	21.4	1.5
Morningside H.S.	J2	86.0	3.4	63.2	3.9	22.8	1.1
	V2	76.0	8.4	54.5	6.3	21.5	3.5
Centinella Hospital	5114	68.3	3.5	40.8*	1.9	30.0*	1.7
	8128	68.9	3.2	42.6**	1.5	29.9**	1.0
Westchester H.S.	F9	67.2	5.4	51.3	4.9	16.0	1.3
Imperial Hospital	227	69.4	2.3	46.0	2.0	23.3	2.3
	224	69.2	2.3	47.4	1.9	21.3	2.7

* Counting only 5 interior measurements above background.
**Counting only 4 interior measurements above background.

PREDICTED NOISE REDUCTION

Suitable methodologies exist for predicting the noise reduction properties of a building/room based on the design, materials used, and structural elements of the building. The methodology used in this study is the Exterior Wall Rating (EWR). The EWR is a single number rating resulting from the summation of transmission losses associated with the individual construction elements (i.e., roof, ceilings, walls, doors, vents, window glazing, etc.) of the building. By coupling the EWR with the absorption properties of the room a noise reduction value was computed.

MEASURED VS PREDICTED NOISE REDUCTION

Using the prediction methodology described above, noise reductions were calculated for each of those buildings where noise measurements were taken in the Los Angeles, Denver and Boston areas. These calculated values for the Los Angeles buildings are shown in Table 2. A comparison of the predicted and measured noise reduction for buildings in Los Angeles is shown in Table 3. A summary of the statistical analysis of the differences between predicted and measured noise reduction in all areas of measurement (Los Angeles, Denver and Boston) is provided in Table 4.

While there are incremental differences between measured and predicted noise reduction values, the 90 percent confidence limits, about the mean (Table 4), indicate a maximum difference of ± 1.45 dB. Considering inherent field measurement inaccuracies of typically ± 1-2dB together with prediction methodology limitations, the variances between measured and predicted values fall within an acceptable range of tolerance. Thus, the noise reduction measurements taken support the prediction methodology used for projecting national data.

Table 2

Calculated Noise Reductions-LAX

		Element Area X Transmission Coefficient					
Building	Room	Windows	Doors	Walls	Roof	A (Sabines)*	NR (db)
Imperial School	2, 11	.1846	.0317	.0036	.0014	1250	26
	6	--	.0317	.0108	.0014	1000	32
Lennox H.S.	4 Bldg 3	.167	.126	.0043	.0014	630	21
	3 Bldg 6						
	3 Bldg 4						
Felton Ave. School	9, 5, 11	.428	.013	.020	.0451	630	19
Clyde Woodworth School	4	.3772	.1912	.0826	.0015	630	18
Morningside H.S.	J2	.3675	.1207	.004	nil	500	18
	V2	.1647	.1207	.004	nil	500	20
Centinella Hosp.	5114, 8128	.0225	--	nil	--	125	26
Westchester H.S.	F9	.3899	--	.0024	.0075	500	19
Imperial Hospital	227, 224	.036	--	.0003	--	140	24
Figueroa St. School	Classroom	.1902	--	.001	.0113	500	22
Lawndale H.S.	Lower Story	.114	.110	nil	--	630	23
	Upper Story	.244	--	nil	.009	630	23

*A sabine is defined as a unit of acoustic absorption equivalent to the absorption by one square foot of a perfect absorber.

Table 3

Predicted and Measured Noise Reduction-LAX

Building	Room	Predicted (dB)	Meas'd (dB)	Δ (dB)
Imperial School	2	25.8	28.9	-3.1
	11	25.8	27.5	-1.7
	6	31.8	31.8	0
Lennox H.S.	4 Bldg 3	21.4	20.4	1.0
	3 Bldg 6	21.4	21.6	-0.2
	3 Bldg 4	21.4	18.0	3.4
Felton Ave. School	9	19.2	18.3	0.9
	5	19.2	18.1	1.1
	11	19.2	19.2	0.0
Clyde Woodworth School	4	18.0	21.4	-3.4
Morningside H.S.	J2	18.3	22.8	-4.5
	V2	20.1	21.5	-1.4
Centinella Hospital	5114	25.7	30.0	-4.3
	8128	25.7	29.9	-4.2
Westchester H.S.	F9	19.0	16.0	3.0
Imperial Hospital	227	24.0	23.3	0.7
	224	24.0	21.9	2.1

Table 4

Summary of Statistical Analysis of Differences Between Predicted and Measured NR
(In Decibels)

Airport	N*	Mean	σ**	90% Confidence Limit Lower	90% Confidence Limit Upper	90% Confidence Limit About Mean
LAX	17	-0.62	2.55	-1.70	0.46	±1.08
BOS	14	1.35	2.34	0.24	2.46	±1.11
DEN	11	-1.06	2.65	-2.51	0.38	±1.45

*No. of rooms measured for each city

**Standard Deviation

CHAPTER 3

MAGNITUDE AND DETERMINATION OF NOISE IMPACT

EXTERIOR NOISE LEVELS

A building's exterior noise impact varies as a function of aircraft noise source level and operational flight path, noise metric used and the building location in reference to the noise source. The following conditions and assumptions were considered in estimating the exterior noise levels of buildings within the study.

--Maximum single event A-weighted sound level.

--Fleet median aircraft type.

--Takeoff thrust, uniform departure paths.

--Incremental sound level contours

--Building location with respect to noise source.

While simplistic in noise exposure concepts, use of the average maximum single event sound level was considered more manageable and appropriate to the objectives and constraints of the study. Also, if desired, incremental noise reductions can be used in developing an equivalent cumulative metric resulting from building modifications relative to single event analysis.

Analysis of the different commercial jet aircraft types and their performance characteristics indicated that an average, or fleet median aircraft type noise source could be used for determining exterior noise impacts. The fleet median type used, from Figure 2, is a two-engine narrow body jet aircraft (e.g., DC-9 or B737). This source noise is also applicable to a small business jet when a slight adjustment of approximately -4 dB is made.

The noise source level of the fleet median aircraft is based on maximum allowable takeoff thrust for a standard sea level day. The takeoff gross weight is that for a medium-range stage length (approximately 800 n.m.). The departure flight tracks are assumed to be straight out on the departure runway heading. A uniform climbout profile is assumed. Based on these conditions, contours covering impacts from 110 to 65 dB were developed in increments of 5 dB.

The contours developed were overlayed on U.S. Geological Survey maps with building sites located. The noise impact level was read directly, or by interpolation, for each site.

Departure Noise Levels for Commercial Jet Aircraft
(Takeoff Thrust)

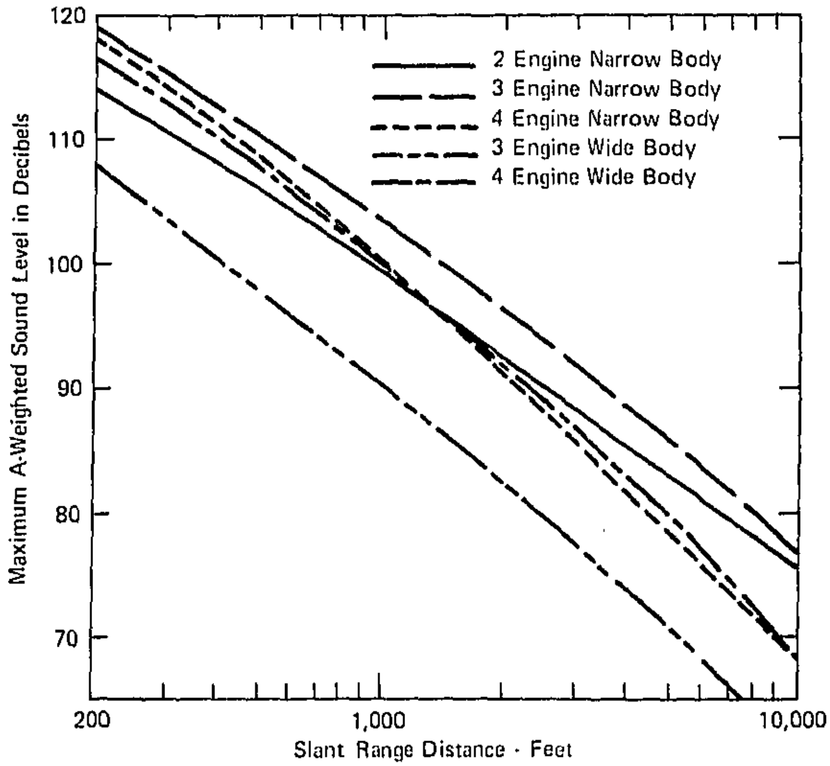


Figure 2

INTERIOR NOISE LEVELS

The noise level inside a room is a function of exterior noise impacts, building attenuation and absorption properties, and internal ambient levels of noise generated by occupancy use of the room. Essentially, interior noise levels are a balance between noise sources and losses. This study did not consider internal noise generated by normal occupancy and use, but such would be a consideration on a case-by-case evaluation. Based on external noise impact only, the interior levels determined for the study become a function of the noise transmission through the building's structure and the absorption properties of the room. Simply stated, interior noise levels equal exterior noise impact minus the building's noise reduction capability (transmission losses through walls and absorption of interior surfaces).

Measured noise reduction, exterior minus interior levels, in units of decibels, was determined for each of the 60 study buildings investigated in the on-site field analysis portion of the work. Using the information gathered as to building design, construction, size, condition, etc., transmission losses were calculated, assuming all windows and doors closed, through application of the Exterior Wall Rating methodology, previously referenced. The interior absorption properties of the rooms were determined through measurement and calculation. While interior absorption values did vary among buildings, the differences were not considered significant in determining noise reduction levels. Constant interior absorption values were used for both classrooms and hospital rooms.

Analysis of the individually determined noise reduction values indicate, independent of regional differences, that an average of 21 dB noise reduction was applicable to 90 percent of all schools. The average for the remaining 10 percent was 29 dB. Less data were available for hospitals. However, the national average in noise reduction for hospitals was estimated to be 23 dB. These averages, proportioned for schools, were used in determining interior noise levels on a regional and national basis.

NATIONAL INTERIOR NOISE LEVELS

The interior maximum A-weighted sound levels of the schools, hospitals and public health facilities identified in the study, due to aircraft noise, are listed in the following table. These national values are a summary of regional data which were established as a result of the calculated differences between predicted exterior levels due to aircraft noise and the noise reduction of the building types.

Table 5

National Summary
Interior Noise Levels

Interior Maximum A-Weighted Sound Levels (dB)	Schools Number of Buildings	Schools Number of Students	Hospitals* Number of Buildings	Hospitals* Number of Patients
Less than 40	--	--	--	--
40-44	20	17,000	--	--
45-49	37	27,000	2	800
50-54	90	69,000	10	3,000
55-59	150	109,000	18	6,500
60-64	215	146,000	25	7,400
65-69	234	149,000	17	6,600
70-74	203	123,000	12	5,300
75-79	76	48,000	2	800
80-85	32	19,000	3	400
Total (Rounded)	1,100**	707,000	90*	31,000

* Includes Public Health Facilities

**Includes both public and private facilities

CHAPTER 4

REHABILITATION

As used in this study, rehabilitation covers the aspects of modifying existing buildings-rooms for soundproofing purposes. The results provide increased noise reduction values and lower interior noise levels.

Soundproofing buildings consists of eliminating or reducing the exterior to interior transmission of sound and improving the absorption properties of the room's interior. While improving interior room absorption contributes to lowering interior levels, the net effect is small in comparison to improvements attainable through increasing transmission losses of walls and ceilings. Although absorption properties are included in establishing incremental improvements in noise reduction, major emphasis is given to those modifications affecting transmission paths and losses.

BUILDING MODIFICATIONS

Soundproofing an existing building consists of identifying the elements which provide transmission paths into the building, then applying appropriate modifications. Up to a certain point, modifications can readily be identified from comparative transmission loss. For example, if an unsealed hollow-core door is the only transmission path, a 10 dB improvement can be obtained by replacing it with a weatherstripped solid-core door.

Slightly more sophisticated modifications include adding insulation and/or layers of paneling to existing walls.

Soundproofing is very much a leak-sealing process. The largest "sound leaks" are attended to first, within the context of the particular building. As an example of soundproofing effectiveness, a 10 dB improvement in the building's noise reduction capability corresponds to an effective halving of the perceived loudness of noise.

In view of the above considerations and the noise reduction prediction methodology, incremental improvements in noise reduction were calculated for feasible degrees of soundproofing modifications.

Modifications considered include:

--Replace existing windows with sealed double glazing with EWR = 40. This is accomplished with acoustic window designs having a sound transmission class rating of 40. An alternative is to install a second layer of glass with at least a 2" air space, and absorptive material around the building. Both layers of glass must be at least 3/16" thick and well sealed.

--Upgrading doors and seals. In some cases "acoustic seals" specifically designed for noise insulation are required. Examples are neoprene seals which are tightly compressed by the door and mechanical drop seals at the bottom. These seals provide a higher degree of airtight closure than does ordinary weatherstripping.

--Acoustic baffling of vents. These are custom-designed baffles which provide an absorptive sound strip without restricting air flow. These can be required for ventilated attic spaces and through-the-wall unit ventilators.

--Adding insulation to walls and attic spaces.

--Adding another layer of material, in effect creating a two-panel wall where the original wall is considered to be the first panel. The new gypsumboard or plaster is mounted on studs, furring strips, or a layer of fiberboard. Using fiberboard improves the transmission loss of a frame or block wall by at least 10 dB, and requires less space than studs or furring strips.

--Eliminating windows and filling the space to match the exterior walls.

The modifications considered feasible and practicable were calculated for the 60 study buildings, producing incremental improvements in noise reduction. In analyzing the results of these calculations, it was found that certain modifications could be grouped into categories which provide the same order of improvement in noise reduction. Modifications were classified in two categories:

-- Category A modifications include replacing existing windows with sealed double glazing, providing mechanical ventilation as needed, installing weatherstripping, replacing doors, insulating walls, ceilings, and attics.

These modifications when applied individually or in combination, provide an improved incremental noise reduction of approximately 10 dB.

-- Category B modifications include eliminating windows and filling space with existing wall materials, adding interior walls and ceiling tiles, installing acoustic double doors, building entrance vestibules, installing acoustic attic baffles, and installing mechanical ventilation.

These modifications applied in the same context as those for Category A, provide an improved incremental noise reduction of approximately 20 dB. Category B modifications are the practicable limits of applied soundproofing within the study.

The use and application of the category concept is to provide comparable noise reduction values for estimating purposes. The modifications used under each category vary as a function of the existing regional building and a given level of noise reduction. In practice a different extent of soundproofing could easily be determined and applied depending on the locally determined needs.

The application of either Category A or B modifications provides, in addition to quantifiably improved noise reduction values, a basis for estimating representative costs of specific levels of soundproofing.

THRESHOLD NOISE LEVELS

The noise impact within buildings, due to aircraft operations, covers an extensive range of levels. In providing quantifiable findings, upper and lower levels of noise impact are required. The upper levels, discussed in Chapter 3, are directly related to aircraft noise source impact. Defining the lower levels required research and analysis.

The lower levels, by definition, are threshold levels of interior noise. Two threshold levels were determined and used, one for schools, and another for hospitals and public health facilities. These A-weighted sound levels are:

--Schools	45 dBA
--Hospitals and Public Health Facilities	40 dBA

These threshold levels are not, nor should they be taken to be, acoustic criteria, specifications or standards regarding building soundproofing requirements. They are simply the lower limits of interior noise levels utilized in the study's analysis, costing and findings.

DEVELOPMENT

Threshold levels were developed under the rationale and within the objective of avoiding interference with noise-sensitive activities.

The adverse effects of noise exposure on people can be grouped into three general categories: degradation of health, attitudinal reactions, and activity interference. In general, the noise levels defining the threshold of interference with certain noise-sensitive activities (i.e., sleep and speech) are lower than those associated with the other two categories of adverse effects. For this reason, activity interference is the criterion used in establishing threshold noise levels for each type of public building considered.

Although a variety of activities exists within any building, activities can be identified for each building type on the basis of primary activity requirements and susceptibility to noise intrusion. The building types considered were schools, hospitals, and public health facilities. For schools, the primary consideration for interior noise is speech communication. For hospitals, the primary activity of importance in regard to the noise environment is sleep. With the functional similarities between hospitals and public health facilities, it is assumed that the primary activity for public health facilities is also sleep. Based on the considerations described above, a literature review determined the noise levels below which interference with the activities of speech and sleep should not occur.

SPEECH INTERFERENCE

The aircraft noise transmitted to the interior of buildings is considered a background noise capable of interfering with speech communication. Such interference is a function of several factors:

--Noise level and spectral content of the background noise at the listener's ear.

--Spectral characteristics and voice effort of the speaker.

--Propagation of the speaker's voice to the listener(s). For typical indoor communication, conducted without the aid of any amplification, this propagation depends upon the separation distance between the speaker and listener(s) and the acoustics of the room.

For speech communication in a classroom situation, at least two additional factors are also pertinent:

--A noise environment which is conducive to learning is required. (For example, repeated short-term disruptions of speech communication can degrade the efficient flow of verbal instruction and lessons.)

--Children are not as familiar as adults with language and, therefore, according to existing research, should have lower background noise levels to achieve the same degree of speech comprehension as adults.

Considering these factors, the following procedure identifies the threshold level of speech communication in school buildings.

--Representative aircraft background noise levels were predicted for locations inside a school classroom. These levels were based on extensive data on outdoor aircraft noise spectra and outdoor/indoor noise reduction values of buildings.

--Data published on the level and spectrum of a female voice exhibiting a raised vocal effort were used to estimate the speech level at a conservative distance of 9m (29.5 ft) from the speaker. (Based on the acoustic reverberation measurements conducted in school classrooms for the study, this separation was more than sufficient to place the listener in the reverberant sound field of the speaker's voice.)

--A standard method for predicting speech communication efficiency, based on use of the Articulation Index (AI), was employed to predict the amount of speech interference for various levels of aircraft noise inside the hypothetical classroom.

The results of this analysis are summarized in Figure 3. This illustrates how the AI increases as the background noise level decreases.

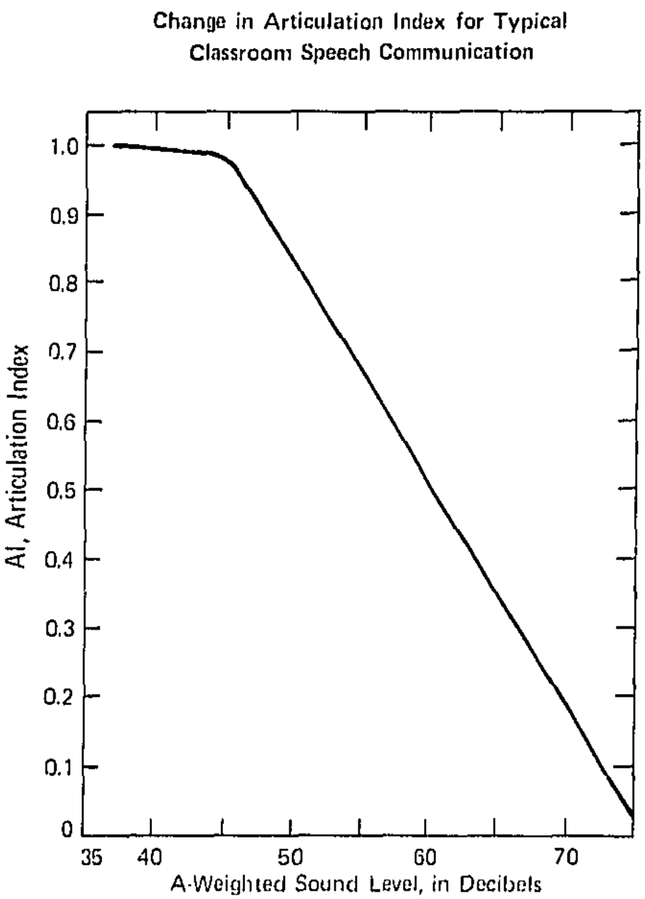
From this more abstract measure of speech communication efficiency, it is possible to predict the intelligibility of complete sentences as a more direct measure of communication effectiveness. For an AI of 0.98, 100 percent intelligibility of first-presented sentences and 98.6 percent correct identification from a list of 1,000 phonetically balanced words are obtained for adults.

As indicated in Figure 3, an AI of 0.98 is obtained when the background A-weighted sound level is 45 dB in the classroom situation considered in this analysis. Further reduction of the background noise level would produce no substantial increase in AI or in sentence intelligibility. Therefore, a level of 45 dB, due to intrusion of aircraft noise inside school buildings, was selected as the threshold level for onset of speech interference effects in such buildings.

SLEEP INTERFERENCE

Because sleep may be crucial to patient recovery, and is a critical activity for patients in hospitals, interference with sleep is the criterion used in the consideration of the noise environment of hospitals. Unlike communication interference, the effects of noise on sleep are not well understood. Experimental research has been concentrated on associating sleep interference with given noise environments for either the awakening of a subject due to a particular noise presentation or a change in sleep stage as determined by physiological indicators.

Figure 3


Change in Articulation Index for Typical
Classroom Speech Communication
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
AI, Articulation Index
35
40
50
60
70
A-Weighted Sound Level, in Decibels

No clear evidence was found to establish any one type of noise metric as preferred for evaluating sleep interference effects. Efforts to collapse the wide variety of experimental data in terms of energy-average values of the various types of noise evaluated have only been partly successful. One investigator has, in fact, been able to estimate the approximate change in sleep interference responses simply in terms of A-weighted sound levels.

These estimates, shown in Figure 4, indicate the approximate number of people who would;

(1) have their sleep state changed, or

(2) be actually awakened as a function of the sound level of exposure.

The lines in the figure represent only the estimated mean trend in sleep interference data with results of individual investigations scattered as much as ±9 dB about the mean trend lines illustrated.

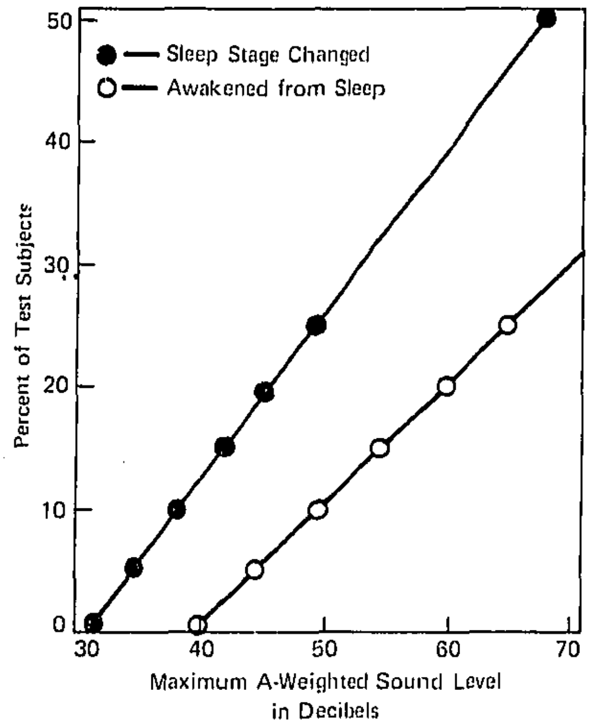
Based on the intercept of the "awakened" trend line in Figure 4 with the zero response axis, an A-weighted sound level of 40 dB was selected for the threshold level of noise for patients in hospitals and other public health facilities. The potential scatter of experimental data, obtained primarily under laboratory-like conditions, about these trend lines, makes it difficult to evaluate reliably the sensitivity of this threshold limit for sleep interference to changes in the limiting level. Increasing the noise exposure above the threshold limit level of 40 dB would cause the expected number of people awakened to increase by approximately 1 percent per dB, and the number of people whose sleep state was changed to increase by about 1.3 percent per dB.

SUMMARY

Interior levels for defining the threshold for effects on people were established for schools, hospitals and public health facilities. Noise exposure to levels below these are not expected to produce any interference effects on people.

Figure 4

Sleep Interference Versus Maximum
A-Weighted Sound Level



CHAPTER 5

COSTS

Nationwide, the estimated cost of rehabilitating aviation noise impacted schools, hospitals and public health facilities to a feasible and practicable level of soundproofing modification would be approximately $204,000,000 spread over a period of years. This value is based on 1977 dollars, excluding factors or provisions for cost escalation. The total amount is the sum of regional costs, developed from assumed modifications applied to 60 study buildings.

COST DEVELOPMENT

Values developed are the dollars which would be required to improve the noise reduction of existing buildings on a region-by-region basis. The costs to achieve improved noise reduction vary by region due to the rehabilitation modification necessary, construction practices employed, material used and local labor rates. However, the methods and procedures for cost development are the same for all regions.

METHODS AND PROCEDURES

Sixty study buildings form the basis of estimating soundproofing costs. The cost was calculated to modify each of these buildings, grouped by region, to achieve the improved noise reduction of Category A and B rehabilitation. Each element of the modification was estimated separately. The total cost of the modification is the sum of all elements. Element cost was developed from a common cost data base of national construction unit cost figures. Unit cost figures were adjusted for regional variations in material and labor by regional cost factors.

Based on the individual building's modification and costing analysis, an average modification and cost were developed and applied to all buildings in the region. Separate analysis was performed for schools and hospitals (public health facilities were considered hospitals in this procedure).

COST DATA BASE

The cost data base includes the unit costs of all elements in the modification including regional cost adjustment factors and the "markup" dollars. The rehabilitation "markup," including overhead, profit and contingency, is a uniform 25 percent of the modification cost. The three basic cost references used to develop the unit cost figures were:

-- The 1977 Dodge Construction Systems Costs, New York: McGraw Hill Information Systems Company

-- The 1977 Dodge Manual for Building Construction Pricing and Scheduling, New York: McGraw Hill Information Systems Company

-- Hospital/Healthcare Building Costs, Farley, J. H., Chief Editor, New York: McGraw Hill Information Systems Company

These manuals are comprehensive and accepted in construction pricing practices. The cost figures are based on national cost averages which are updated periodically from information collected at actual on-job sites throughout the country. Current values represent early 1977 prices. Basically, the values show labor, material and total costs in square feet of intended modification. Thus, the modifications applied in the study are in terms of square footage of work to be done, except in the instance of Heating, Ventilating and Air Conditioning (HVAC) work. Where HVAC is included, the unit price of HVAC is based on the square footage of the room floor.

REGIONAL COST ADJUSTMENT

While unit cost figures are provided on a national basis, the Dodge Manuals recognize the variances in labor and material costs throughout the nation. Cost adjustment data for the cities listed in each of the study regions were compiled and averaged to produce regional cost factors. Applying regional factors to the national costs adjusts the unit costs up or down, as appropriate to the conditions of each region.

PROGRAM COSTS

The estimated dollar costs for reducing the interior noise levels of existing schools, hospitals and public health facilities to within feasible and practicable limits are considered program costs. These costs and the noise reduction they provide are presented in national values. While valid in this context they are averages and should be used as reference and guidance only. Case-by-case local site evaluation and cost estimating need to be accomplished to determine actual facility rehabilitation costs.

Soundproofing costs, by region, were developed for both schools and hospitals (including public health facilities), by determining:

--The level of noise reduction to be attained (Category A or B).

--Modification to be applied, per room.

--The number of rooms to be modified under each category.

--Cost per room times number of rooms per category.

Regional costs are the sum of all modification costs within the region and national costs are the sum of all regional costs.

A key item in developing costs was the degree of modification assumed to be applied. The criteria used in determining Category A or B improvements were based on the following.

Category modifications are applied in the following manner. Category B modifications (approximately 20 dB improved noise reduction) are applied to those buildings/rooms with existing noise levels of 60 dB and above for schools, and those of 55 dB and above for hospitals and public health facilities. Category A modifications (approximately 10 dB improved noise reduction) are applied to those buildings/rooms with existing noise levels of 50-59 dB for schools, and those of 45-54 dB for hospitals and public health facilities. These criteria also include the feasible and practicable constraints of do-nothing for existing levels below 50 dB for schools and 45 dB for hospitals. Such constraints could be removed on an individual case-by-case evaluation and implementation effort.

NATIONWIDE COSTS

Soundproofing cost estimates are provided, in national values, for schools in Table 6, and for hospitals (including public health facilities) in Table 7.

Nationwide Soundproofing Impact and Costs

Schools

Maximum Interior A-Weighted Sound Levels (dB)	Existing			Rehabilitation*		After		
	Numbers of			Dollars	Dollars	Numbers of		
	Buildings	Rooms	Students	Cat. A	Cat. B	Buildings	Rooms	Students
Less than 40	--	--	--	--	--	--	--	--
40-44	20	688	17,189	--	--	325	9,315	232,569
45-49	37	1,065	26,734	--	--	421	11,407	285,198
50-54	90	2,774	69,150	13,801,000	--	203	4,937	123,244
55-59	150	4,380	109,440	22,234,700	--	76	1,903	47,420
60-64	215	5,853	146,230	--	33,693,000	32	759	18,939
65-69	234	5,962	149,024	--	34,354,000	--	--	--
70-74	203	4,937	123,244	--	28,533,000	--	--	--
75-79	76	1,903	47,420	--	1,071,800	--	--	--
80-85	32	759	18,939	--	4,409,000	--	--	--
Totals (Rounded)	1100**	28,500	707,000	36,000,000	112,000,000	1,100	28,500	707,000

* Limited by feasibility and practicability

** Includes both public and private facilities

Average:

Cost per room Cat. A $5,030; Cat. B $5,750

Improved NR Cat. A 10 ±2; Cat. B 20 ±3

Table 6

Table 7

Nationwide Soundproofing Impact and Costs

Hospitals**

Maximum Interior A-Weighted Sound Levels (dB)	Existing			Rehabilitation*		After		
	Number of			Dollars	Dollars	Numbers of		
	Buildings	Rooms	Patients	Cat. A	Cat. B	Buildings	Rooms	Patients
Less than 40	--	--	--	--	--	18	3,900	7,076
40-44	--	--	--	--	--	37	6,510	10,606
45-49	2	466	754	373,900	--	17	3,988	6,589
50-54	10	1,876	3,046	5,796,800	--	12	3,370	5,289
55-59	18	3,554	6,522	--	11,031,500	2	467	820
60-64	25	4,514	7,360	--	13,234,000	3	255	426
65-69	17	3,988	6,589	--	13,318,200	--	--	--
70-74	12	3,370	5,289	--	9,485,000	--	--	--
75-79	2	467	820	--	1,523,000	--	--	--
80-85	3	255	426	--	776,500	--	--	--
Totals (Rounded)	90	18,500	31,000	6,000,000	50,000,000	90	18,500	31,000

* Limited by feasibility and practicability

** Includes Public Health Facilities

Average:

Cost per room Cat. A $2,630; Cat. B $3,050

Improved NR Cat. A 11 ± 1; Cat. B 18 ± 2

CHAPTER 6

BENEFITS

The principal benefit in soundproofing public buildings is the lowering of interior noise levels of schools, hospitals and public health facilities, thus providing improved conditions for classroom communications and patient rest and recovery. Although little data exist to enable the translation of this direct benefit into dollars, or to quantify the improved educational system, or to quantify the advantages of a shortened recovery period of patients, these aspects can be reviewed on a qualitative basis.

Quantitative benefits of soundproofing can be projected by estimating dollars saved in energy (schools and hospitals) and the dollar value of recovered teaching time. Indications are that benefits also exist in patient recovery time; however, this benefit is more difficult to quantify and has not been estimated. The values derived are based on assumptions and projections, subject to validation, and do not measure the total value of all actual benefits. Therefore, any comparison of the estimated national benefits and estimated national costs, in effect, understates the actual benefits of soundproofing.

QUALITATIVE

SCHOOLS

For schools, the benefit of soundproofing to improve verbal communications in the classroom is reflected in an enhancement of the quality of education and a reduction of stress on teachers and students. Enhancement in the quality of education comes about through increased communication between teachers and students as well as the educational value of reducing interruptions during verbal lessons. Although this benefit could be quantified to some degree by comparing test scores of students exposed to quiet and noisy environments, the value of an improved quality of education is in effect a priceless commodity.

The reduction of stress in the classroom achieved by lower noise levels results from eliminating the need for raised voices and vocal repetition in attempts to maintain communication during noise interruption from outside the building. As with improved educational quality, the reduction of stress is an intangible benefit which affects not only the participants in the classroom but also ultimately their families and society at large.

Figure 5 provides a graphic presentation of qualitative impact benefits in soundproofing schools. Under the existing conditions in schools identified within this study, 84 percent of all students are exposed to interior maximum A-weighted sound levels of 55 dB* or higher associated with aircraft operations. After soundproofing, student exposure to interior levels of 55 dB or higher due to aircraft noise is reduced to less than 10 percent.

HOSPITALS

For hospitals and public health facilities, the soundproofing benefit of reduced sleep interference is directly realized by the interned patients in the form of a health and quality-of-life benefit and a potentially shortened recovery period. Additional benefits can also be achieved in the potential reduction of the time that medical attendants are required by sleep-disturbed patients. The reduction in patient noise impact through soundproofing is graphically presented in Figure 6. Under existing conditions in hospitals and public health facilities within this study, 97.5 percent of all patients are exposed to interior maximum A-weighted sound levels of 50 dB** or higher as a result of aircraft operations. After soundproofing, patient exposure to interior levels of 50 dB or higher due to aircraft noise is reduced to 21 percent.

QUANTITATIVE BENEFITS

ENERGY SAVINGS

The soundproofing of public buildings has two energy related effects;

--Increased energy consumption by air conditioning equipment due to elimination of natural ventilation.

--Reduction in heat loss due to the sealing of walls, windows, and other openings.

A study performed by the Federal Energy Administration, "Energy Conservation in New Building Design," Conservation Paper No. 43, August 1975, indicates that energy savings realized by reduction of heat loss exceed the increased energy consumption of air conditioning (energy costs based on 1977 utility rates).

The energy consumption required and the energy saved through building modifications, including air conditioning as appropriate, were calculated using methodology set forth in a Wyle Laboratories document, "Insulation of Buildings Against Highway Noise," August 1976, which includes the following:

--Net Energy Saving = (energy savings by sealing and modification) - (Added ventilation energy)

* A level of 55 dB is considered the ambient interior noise level of an occupied classroom.

** A level of 50 dB is considered the ambient interior noise level of an occupied hospital room.

Schools
Students Impacted

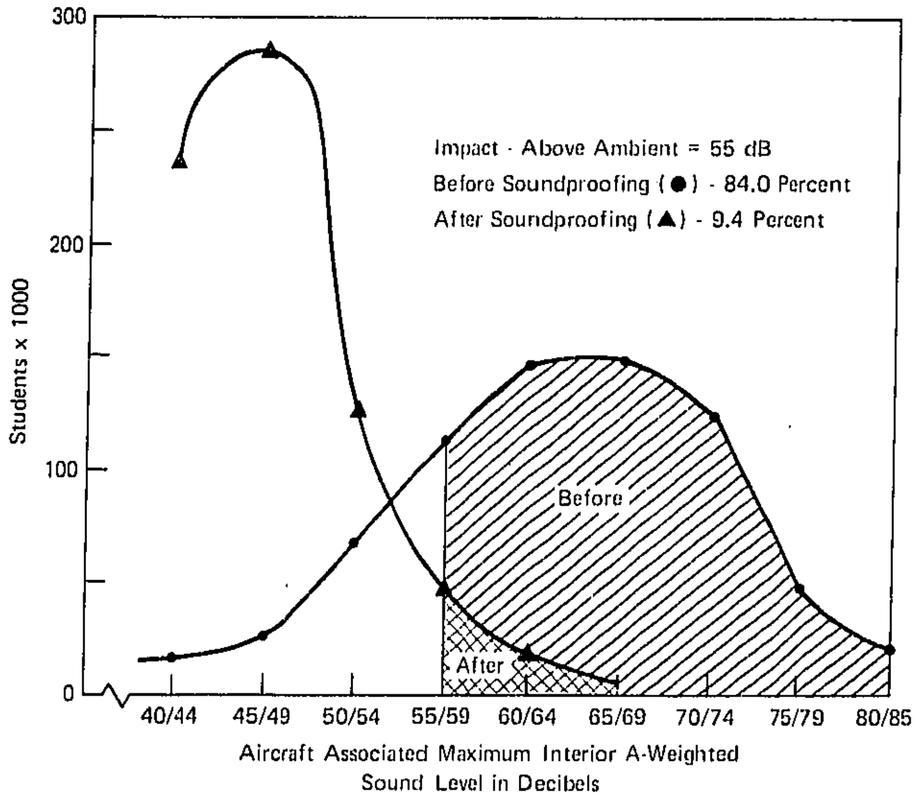


Figure 5

Hospitals (PHF)
Patients Impacted

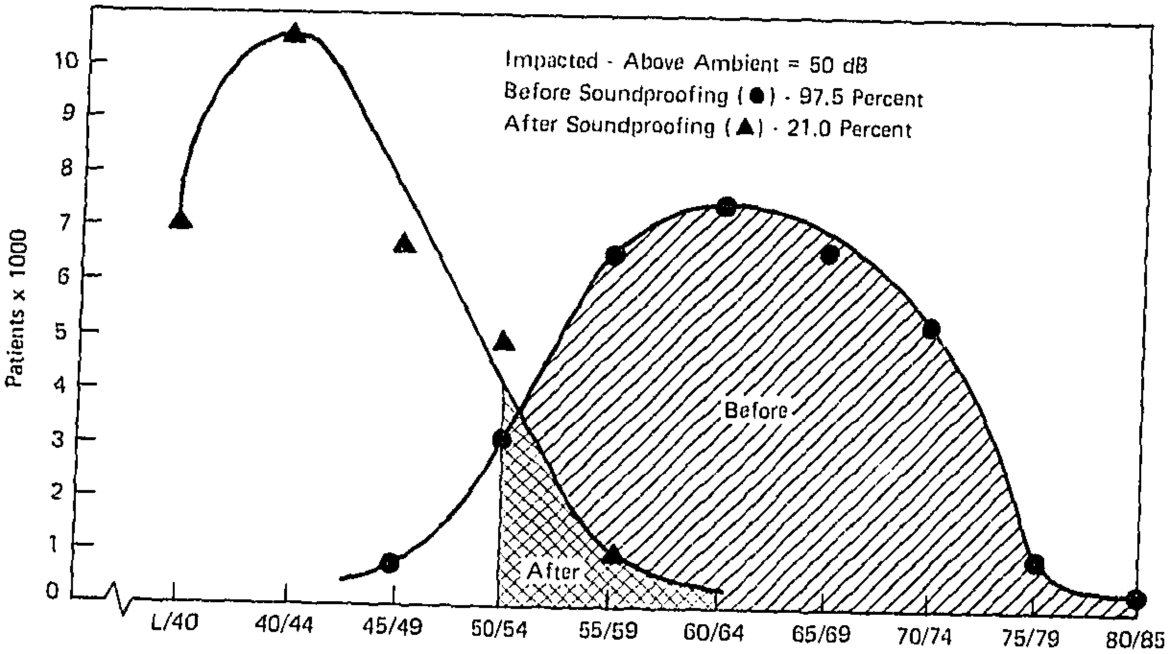


Figure 6

--Energy Saving by Sealing = (Infiltration constant (C)) x (Building Volume) x 365* x 24

--Energy Saving by Modification = (Thermal Transmittance (u) Factor) x (Area) x (Local Annual Degree/Day x 24)

--Added Ventilation Energy (kwh/year) = $\frac{\text{Building Volume}}{233}$

--Weighted average energy cost for gas, oil, and electricity is applied to the above energy consumption to translate into 1977 dollar costs.

The results of these calculations, in energy dollars saved, for the 1190 public buildings covered in the study are listed below. The calculations were made assuming that all buildings would have heating, ventilating and air conditioning systems.

NET ENERGY SAVINGS PER YEAR

BUILDING TYPE	NUMBER	NET SAVINGS (77 $)
Schools	1100	1,780,000
Hospitals	78	230,000
Public Health Facilities	12	30,000
TOTAL		2,040,000

TEACHING TIME RECOVERED

Disruption in classrooms, due to aircraft noise, causes time delays in the teaching process. Soundproofing would reduce these delays and the time recovered can be represented in an estimated dollar value of teaching time. The values determined are based on the soundproofing modifications as applied on a national basis. Therefore, the dollars recovered are representative of average improvements for all schools where modifications were considered. On a case-by-case basis the actual teaching dollars recovered would be directly related to the local school conditions, frequency of disruptions, degree of modification, and numbers of teachers impacted.

* Adjusted to 180 days for schools.

The dollar values of teaching time recovered is spread over the total number of schools, less those (57) which were not modified. Time recovery increments were determined using an average 20 second interruption per flyover multiplied by an estimated average of 10 flyovers per school per day. An average hourly wage rate ($12.40) for teachers was used, which was developed from statistical information compiled by the Department of Health, Education, and Welfare, National Center for Educational Statistics, and is based on 180 (yearly) teaching days of six hours each. Based on an average of 25 students per classroom, the approximate number of teacher's whose time is under consideration is 26,500.

TEACHING TIME RECOVERED

PERIOD	DOLLARS (1977)
Average value per day	18,300
Average value annually (180 school days a year)	3,300,000

(Estimated value of daily teacher time recovered =

$$10 \times \frac{20}{3600} \times 12.40 \times 26{,}500 = \$18{,}300)$$

CHAPTER 7

FEASIBILITY AND PRACTICABILITY

In general, the soundproofing of schools, hospitals and public health facilities impacted by aircraft noise is both feasible and practicable. While feasible and practicable, there are limits regarding the application of soundproofing modifications in achieving specified levels of noise reduction. It is neither feasible or practicable to conclude that all buildings within this study can or would be "soundproofed" to the threshold levels of speech or sleep interference. However, on a national scope, the rehabilitation modifications available, the noise reduction attainable, and the benefits derived support the feasibility and practicability of soundproofing public buildings.

FEASIBILITY

Soundproofing existing public buildings is considered feasible in that it involves structural modifications, or element replacement, which are attainable and available. It is true that all buildings will not attain the same level of noise reduction for a given degree of modification due to differences in design, construction, age, general repair and remaining life expectancy. However, within limits, applying feasible modifications to these conditions provides for improved noise reduction. In certain instances soundproofing would not be feasible. As an example, it would be less than feasible to spend rehabilitation dollars on a building of projected short life use; or, on one which, because of its state of general repair, would have sufficient "leaks" after soundproofing to prevent attainment of the rehabilitation objectives in noise reduction. This situation is the exception rather than the rule.

PRACTICABILITY

The practicability of soundproofing is supported by both technical and design considerations. The architectual and engineering demolition, redesign and reconstruction expertise is available. The labor and material for element replacement and/or modification exist. With but few exceptions the basic existing structures are capable of modifications. For those buildings where desired modifications are not technically practicable, reduced levels of modification having correspondingly lower resulting noise reduction benefits might be considered. Practicable limits could preclude any modification at all.

Further consideration must be given to the scheduling and on-site work period of all building modifications considered. Work should be scheduled and carried out on a least disruptive basis. It would be impractical to disrupt the buildings' use and occupancy, especially hospitals, for extended periods of time.

CHAPTER 8

CONSULTATION AND REVIEW

The consultative process was used throughout the study's development, contractual efforts and during the preparation of this final report. Guidance, data input and views were sought from other Federal agencies, state and local authorities, school and hospital administrations, and recognized organizations having an interest or expertise in the soundproofing of buildings for noise reduction purposes. In addition, international input was solicited. Information was requested from 25 countries regarding their soundproofing programs (if any), its cost, and resultant public benefits.

Various means of program coordination were used, including:

--Correspondence exchange.

--On-site meetings with local authorities.

--Contractual progress briefings (3).

--Distribution of contractual draft report.

--Intradepartmental review.

--Public briefings.

DOMESTIC

In general, Federal, state and local authorities directly involved with noise control programs expressed a positive interest in the study, felt its objectives were very important, and gave full cooperation in on-site investigations and data submission. Some state and local administrations were, however, passive to negative regarding the study or the need for the soundproofing of public buildings.

INTERNATIONAL

The international responses received indicate moderate to extreme interest in a public building soundproofing program. Responses indicate that within seven countries, to varying degrees, a program currently exists.

-- Germany. Soundproofing is not limited to public buildings and is subsidized under the provisions of Article 9 of their Aircraft Noise Reduction Law. Funds are available from the general revenue funds of the airport operators for areas surrounding civil airports and from the Defense Ministry's Budget in the case of military air bases. The amount of the subsidy is fixed by ordinance, and currently is at a rate of 130 Deutschmarks per square meter (equivalent to approximately $6.00 per square foot) of soundproofing rehabilitation. Subsidy payments are made upon application by real property owners. Civil subsidies for the period 1976-1980 are expected to be 45 million Deutschmarks (approximately $18,700,000). No information was obtained regarding the number of buildings soundproofed or the public's reaction to the program.

-- Canada. Soundproofing programs are a local municipal action. The Federal Department of Transport disclaims responsibility. Thus, as a function of funds available, programs are implemented or not by individual cities. Funds are provided from the municipality's Education Capital Budget. Toronto's program includes 25 schools, 7 of which have completed their soundproofing activities. Total estimated costs are approximately $5,000,000 ($200,000 per school average). Public reaction is reportedly favorable where schools have been soundproofed.

-- Japan. A program for soundproofing public buildings has been underway in Japan for approximately 10 years. It is controlled and funded at the national level. Revenue is provided through taxes and user charges. Regulations provide for sudsidies of 75 to 100 percent of the total cost. The average percent of subsidy, over the program's 10 years, is 90%. While Japan's total program includes private homes, emphasis has been placed on public buildings. To date, 725 public buildings have been rehabilitated at a cost of approximately $110,000,000 (approximately $160,000 average per building). $27,600,000 has been budgeted for public buildings yet to be modified. The public is pleased with the results of their soundproofing program, so far.

-- Israel. A formal soundproofing program does not exist, however, two buildings near Ben Gurion Airport have been soundproofed on an experimental basis, at government expense. Neither public reactions nor the costs of this experiment were available.

-- France. Approximately 60 schools and 13 medical buildings have been soundproofed in France. Additionally, France is reported to have established a relocation program concurrent with their soundproofing program. Details of costs and public reaction were not available on either program.

-- United Kingdom (UK). Private dwellings have been and are currently candidates for UK's soundproofing program. To date, consideration has not been given to public buildings. Program costs and public response was not submitted.

-- Netherlands. An existing program parallels that of the United Kingdom.

For those countries where soundproofing programs are in existence, details on the modification or degree of soundproofing were not available. However, the tabulation of actual costs for soundproofing in these countries compare closely with the estimated costs determined in this study. Examples:

COUNTRY	COSTS IN DOLLARS (U.S.)	
	$/Sq Ft	$/Building
United States (Estimates)	6.++	180,000
Germany (Actual)	6.++	-
Canada (Actual-7 Bldgs)	-	200,000
(Est. - 25 Bldgs)	-	200,000
Japan (Actual - 725 Bldgs)	-	160,000
Israel (Actual - 2 Bldgs)	-	-

CHAPTER 9

FINDINGS

Based on the soundproofing study conducted, it was found that:

--Soundproofing of schools, hospitals and public health facilities located near airports is, within limits, both a feasible and practicable means for alleviating the impact of aircraft noise.

--The costs of applying feasible and practicable soundproofing modifications to existing candidate buildings have been estimated to be approximately $200,000 per building. This amount compares closely with the actual costs of soundproofing similar buildings in foreign countries.

--Soundproofing would significantly reduce the impact on students in schools and patients in hospitals and public health facilities (see Figures 5 and 6).

--Soundproofing would provide social and economic benefits beyond improved classroom communications and patient recovery.

--Any soundproofing of public buildings should be sensitive to case-by-case evaluation and assessment of a candidate site.