AIRPORT NOISE
ITS IMPACT AND ALLEVIATION
by
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AIRPORT NOISE: ITS IMPACT AND ALLEVIATION

by

CARL VICTOR ROBART

ABSTRACT

The Problem

Airport noise is a serious problem acutely felt in the cities and metropolitan areas served by large civil airports. The problem is based on the objection of people to aircraft noise that overspills the boundaries of airports and interferes with sleep, conversation, teaching, recreation, and other activities. Present noise alleviation efforts have not yet brought the type of conclusive action which is needed to significantly reduce exposure to high levels of aircraft noise. The inquiry seeks to outline and define in some specifics a systematic approach to resolving the problem of airport noise.

Method

Aircraft noise alleviation measures are evaluated by an analytic scheme involving four variables: effectiveness, scope, cost of implementation, and limitations. The three major categories of alleviation measures are studied: insulation of the receiver, separation of the source and receiver, and reductions at the source.

Results

The effectiveness of most measures in reducing noise exposure near airports is poor. Zoning is largely unsuccessful in excluding noise sensitive land uses near airports. Acoustic conditioning of structures is too expensive. The analysis did indicate that three methods are potentially capable of significantly reducing noise exposure: retrofitting present engines with acoustically treated nacelles, re-equipping the existing fleet with high-bypass-ratio engines, and noise abatement operation procedures. Additionally, both STOL and VTOL promise reductions in aircraft noise exposure. An examination of mechanisms
for coping with environmental problems -- setting standards, subsidies, and taxation or imposition of effluence charges -- showed the latter to be potentially most effective.

Conclusions

The noise impact on people, their communities, and civil aviation, is large and costly and, barring unforeseen intervention, will be even more severe in the future. The most significant lack in present efforts to reduce flight noise is not technology, but a focal point with sufficient authority and funds necessary to produce the comprehensive answer required. The transfer of authority for noise alleviation from the FAA to the Environmental Protection Agency and the implementation of a combination of the more effective measures -- backed by appropriate economic incentives -- are suggested.

Thesis Supervisor: Aaron Fleisher
Title: Associate Professor of Urban Studies and Planning
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BIOGRAPHY OF THE AUTHOR

Carl V. Robart was born in Seattle, Washington. After graduating from Washington State University in 1965 with a B.A. in Mathematics and completing the Master of Urban Planning program at the University of Washington in 1967, he spent three and one-half years at MIT, studying for a doctorate in Urban Studies and Planning. He now is Manager of Environmental and Urban Studies at R. Dixon Speas Associates in Manhasset, New York.

Mr. Robart, a member of the Tau Sigma Delta, has worked on the staff of the Flight Transportation Laboratory at MIT, and as an Urban Planning Department Research Assistant at the University of Washington. His work has been published in the University of Washington Urban Planning/Development Series and industry publications. Mr. Robart and his wife, Margaret, have a daughter, age three.
PART 1
CHAPTER I

THE AIRPORT NOISE PROBLEM

The objective of this chapter is to introduce the specific problem to be studied in this dissertation, airport noise, to examine the status of the problem as a challenge to environmental quality, and to use this information to frame the objective of the dissertation.

Airport Noise and Environmental Quality

It is imperative in applying technology to serve man's needs, to take into consideration the impact of the applications on the environment. In this introductory section, the significance of noise as an adverse effect on environmental quality is discussed.

The Noise Problem. Noise is everywhere, especially in urban areas. The roar of transportation, the general din and hum of construction projects, and industrial noise all pound against the ear.

In the decade of the 1960s, the President's Council on Environmental Quality reported the measured amounts and extent of urban noise significantly. At the same time, public awareness of noise and the discomfort caused by it was increasing.
While much of the environmental noise is associated with activities which are essential to the economic vitality of the country, the intrusion of excessive noise diminishes the quality of life and is unacceptable.

In airports and the area surrounding them, major noise problems have been created by the rapid growth of aviation since World War II and the development of jets.

**Airports and The Increased Concern with Environmental Quality.** The objective of this section is to determine the significance attaching to problems of environmental degradation, specifically those caused by airport noise. Federal Government action in response to environmental conditions is used as a measure.

Federal Government action has swelled in the past two years. The most important single action was the enactment of the National Environmental Policy Act of 1969 (Public Law 91-190). This Act contains a declaration of national environmental policy which recognizes the importance of environmental quality and the government's responsibility to protect and improve the environment. The Act provides for the Council of Environmental Quality and requires that the policies, regulations, and public laws of the United States be interpreted and administered, in accordance with environmental policies and goals.
Section 102 (2), (c), of the Environmental Policy Act insures that all Federal agencies give attention and appropriate weight to environmental goals in all their decisions. Every airport development action potentially involving Federal financial aid falls within the purview of the Environmental Act.

Another important legislative action which bears on airport development and environmental quality is the Airport and Airway Development Act of 1970 (Public Law 91-258). In addition to providing for substantial expansion and improvement in the nation's airport and airway system, the Act contains important environmental and planning preconditions to the assistance of airport development projects. Sections of the Act direct that no major airport development project shall be authorized for receipt of Federal financial aid unless:

. The project provides for the protection and enhancement of the natural resources and the quality of the environment of the nation.
. There is reasonable assurance that the project will be located, designed, constructed, and operated so as to comply with applicable air and water quality standards.
. The interests of communities in or near which the project is proposed are considered.
Alternative actions that will minimize adverse impact have been explored and further, that the long and short-range implications to man, his physical and social surrounding, and to nature are evaluated.

The agency sponsoring the project affords the opportunity for public hearings to consider what economic, social, and environmental effects the project may have.

Summed up, the new Federal thrust in environmental matters is that if development actions involving Federal financial aid, including airport development, have environmental effects, the impacts should be explored along with possible alternatives to the proposed actions. The strength of the Federal Government's commitment to preventing environmental degradation is reflected in these two recently enacted environmental acts and indicates the high level of significance attached to the problem.

Growing Recognition of the Airport Noise Problem

It was observed in the introductory section that degradation of the urban environment has resulted from many different influences. The specific issue raised now is the problem of jet aircraft noise. The objective is to assess present efforts to alleviate airport noise caused by jets. Accordingly,
this section describes the basis of the airport noise problem and comments on current alleviation efforts.

Airport noise has been a growing problem most accurately felt in the cities and metropolitan areas served by large civil airports for over a decade. The problem is based on the objection of people to aircraft noise that overspills the boundaries of airports and interferes with sleep, conversation, teaching, recreation, and other activities.

Industrial safety standards have been set to limit noise exposure in manufacturing plants and other situations where permanent damage to hearing could occur, but recognition of noise as an environmental problem has arrived late in the country. Recently, it has been recognized that cities are confronted with serious aircraft noise problems.

Public Law 90-411 enacted in early 1969 added a new section to the Federal Aviation Act of 1958, legislating aircraft noise standards. The Act provides that:

"The Administrator of the Federal Aviation Administration...shall prescribe.....such rules and regulations as he may find necessary....for the control and abatement of aircraft noise and sonic boom...."

---

1 Public Law 90-411.
The Federal Aviation Administration (FAA) requires that new subsonic aircraft be about ten EPNdB quieter than the loudest jets currently flying. The maximum level for ground operation, takeoffs, and approaches is set at from 93 to 108 EPNdB, (the lower level for aircraft weighs under 75,000 pounds, the upper level for those weighing 600,000 pounds or more) -- down from 110 to 120 decibels.

Steps are being taken to reduce aircraft noise at the source. NASA has sponsored several efforts to design, fabricate, and test experimental techniques for quieting turbine engines. The FAA Office of Noise Abatement has investigated the economic impact of implementing acoustically treated nacelle and duct configurations.

Growing public concern is reflected in the proliferation of associations, special study or task forces, and pressure reaction groups concerned with noise; for example, Citizens League Against the Sonic Boom; NOISE (National Organization to Insure Sound-Controlled Environment), or Citizens for a Quieter New York.

These various efforts reflect a growing increase in concern and effort, but they have not yet brought the type of conclusive action which is needed to significantly reduce exposure to high levels of aircraft noise. Before aircraft noise pollution
problems reached the point of widespread public response, the air transportation industry entrenched itself in heavy equipment investments and so committed itself to laissez-faire rules of business that controls rigorous enough to bear on noise are constantly in danger of being compromised below the point of effective response. The time for effective action is before a problem becomes irresolvable. If aircraft noise exposure is to be controlled and even worse conditions prevented in the future, it is certain that a variety of decisive steps must be taken now based on available knowledge. To wait longer, is to be too late.

Objective of This Dissertation

From this examination of the airport noise problem, the need for immediate action to bring about its resolution has been identified. The objective of this dissertation is to outline and define in some specifics a systematic approach to resolving the difficult issue of airport noise.

To do this, calls first of all, for an understanding and explanation of the history of community response to airport development and the noise buildup. It also demands perception of noise exposure measurement and the specific ways in which the effects of aircraft noise are felt. The first can be done by study of selected cases. The second calls for extensive investigation of noise as a physical phenomenon and environmental influence.
As with every form of environmental pollution, prevention or abatement of aircraft noise can be achieved only at an economic cost. Before costly actions are implemented, answers to a number of questions about noise alleviation are essential. Is there justification for expenditures to alleviate noise? From where should the impetus to alleviate noise originate? How should the costs of noise alleviation be allocated and upon whom should they fall? The purpose of the latter chapters of this dissertation is to answer these critical questions.

Dissertation Structure and Data Sources

This section describes the structure and data sources of the dissertation. The dissertation is structured as follows: Chapter II is a resume of the history and present status of airport-community relations developed by reviewing circumstances at three major airports. Chapter III examines the phenomenon of noise and how community exposure to aircraft noise is measured. In Chapter IV, some of the many ways in which noise problems have direct and indirect effects on people, environmental quality, and civil aviation are discussed. Chapter V describes how noise reduction programs may be evaluated. Chapter VI and Chapter VII evaluate the means which exist to lower community noise exposure and conclude with an assessment of available noise alleviation measures. Chapter VIII addresses the issues of
pollution economics and costs. Final conclusions of the dissertation are drawn in Chapter IX.

Data for this dissertation is derived from a variety of sources. Articles from technical journals; consultant reports; MIT Flight Transportation Laboratory Technical Reports; Federal Government publications (especially those of the FAA); and newspaper articles make up the bulk of sources from which information has been drawn. Extensive use was made of the Flight Transportation Laboratory Data File and the Technical Library of R. Dixon Speas Associates, Aviation Consultants. In addition, the author interviewed many airport, air carrier, and government officials charged with responsibility for airport noise problems. The author benefited from many discussions with the faculty and staff of the MIT Flight Transportation Laboratory and the professional staff of R. Dixon Speas Associates.
CHAPTER II

THE COMMUNITY-AIRPORT INTERFACE

Introduction

Reference to the need for study of cases was made in Chapter I. Lack of documentation of airport-community relations historically in a published form readily available makes the examination of cases crucial to get a proper fit for the anticipated systematic approach to the resolution of the airport noise problem. One objective of this chapter then is to provide needed insight into the character of the community-airport interface with specific reference to the issue of aircraft noise.

The principle that the airport noise problem should be resolved rests, in part, on the hypothesis that without its resolution the air transportation industry will be unsuccessful in obtaining needed community and political approval for future expansion of existing airports or development of major new facilities. The second objective of this chapter is to comment on the validity of this hypothesis.

The selection of cases for study must be made with great care. One cannot take just any case and project the findings for a larger universe. Likewise, the selection of cases is limited by the mobility of the student. To be representative
of the range of metropolitan areas experiencing noise problems, it is necessary that a sample be taken which covers major contingencies.

Material on three airports has been assembled to facilitate this task. The three airports selected for study are: Logan Airport in Boston, J. F. Kennedy Airport in New York, and Dulles Airport in Washington, D. C. Logan was selected as an example of an airport fitting into a built-up, old, community; Dulles as an example of an airport fitting into a development community of recent origin; and J. F. Kennedy Airport as an intermediate between the two. Comparisons between these three airports are possible because each airport serves a major metropolitan area within the same geographic region, and thus, they share similar operational environments.

Airport Case Studies

Boston.

1. Surroundings. General Edward Lawrence Logan International Airport ("Logan") is located adjacent to the communities of East Boston, Revere, and Winthrop in what were originally the northern tidal flats and shallows of Boston Harbor. The airport is well located in relation to downtown Boston, being only five-to-ten minutes from there (traffic permitting) by auto or rail. The geographic relationship between Logan, communities in the Boston area, and the harbor and ocean may be seen from the map, Figure II-1.
Today, the communities of East Boston and Winthrop, and the portions of Revere which lie near the airport are largely residential. The 1967 "Comprehensive Land Use Inventory Report", by the Massachusetts Metropolitan Area Planning Council, described each municipality of the Eastern Massachusetts Regional Planning Project. ¹ "Residential Density", (number of dwelling units per acre) and the distribution of housing types (as single-family, two-family, and multi-family) were among the facts presented as averages for each entire city or town. Boston, Revere, and Winthrop were in the group having the highest density (more than eight dwelling units per acre, average), but the distribution of housing types differed.

In the City of Boston, over 50 percent of the dwelling units were in multi-family structures. In both Winthrop and Revere, on the other hand, about one-half of the dwelling units were in single-family structures.

The June 1965, "Survey and Planning Application (R-101, East Boston)" of the Boston Redevelopment Authority (BRA), for East Boston General Neighborhood Renewal Plan (GNRP), describes that part of East Boston which lies generally south

¹ Eastern Massachusetts Regional Planning Project, Comprehensive Land Use Inventory Report, (1967).
and west of Eagle Square. This area is shown in Figure II-2, as zones B-4, B-6, and B-7, and includes the Jeffries Point, Maverick Square, Central Square, Eagle Hill, Day Square, and Eagle Square sections. The East Boston GNRP excludes the areas identified in Figure II-2 as zones B-1, B-2, B-3, and B-5, which include the Bayswater Street/Saratoga Street, the Neptune Road, and Orient Heights sections, (Figure II-3).

The BRA application described land use within the GNRP as largely multi-family residential, with industrial land use spread along the waterfront, and commercial land use mixed with both industrial and residential uses. The area was said to be declining in population and in the number and nature of industrial and commercial activities. The population of all of East Boston declined from a peak of 64,000 in 1925 to 43,000 in 1960. Almost 10,000 persons left the GNRP area in the decade between 1950 and 1960, a 19 percent loss compared to 13 percent for Boston as a whole. However, the resident population was fairly stable with two-thirds of the population of the GNRP area remaining at the same residence during the period 1955-60, compared to a city-wide average of only 51 percent for the same period (U.S. Census Bureau data).

In 1960 in the GNRP area there were 9,820 dwelling units in 3,880 structures, of which 97 percent were judged by the BRA

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as "deficient" in one or more respects. Single-family housing, comprising only 6.7 percent of the total in the GNRP area, had in 1960 a median value of $7,700, as compared to an average of $13,500 for all of Boston. Most of the housing contained two, three, or four units and were of frame, or frame and brick veneer, construction, ranging in height from two to four stories.

Growth of commercial and industrial activities related to the airport has been slight. Demand for vacant land near the airport has been virtually nonexistent. Attempts in 1964 to auction city-owned land along the East Boston waterfront were unsuccessful. Two facts help explain these circumstances. First, as a result of the community's close association with transportation facilities -- even before the airport, East Boston was the locus of transportation facilities -- it has taken much of its character from these installations. The waterfront has been in decline for many years. Large areas in some sections which once bustled with activity are now vacant. On balance, the surrounding environment, marked by blight and deterioration has effectively curtailed development. Second, the proximity of the airport to downtown

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4 Public Auction, held 30 June 1964, of 260,381 square feet of land on New Street, East Boston.
Boston has mitigated against the construction of hotels, convention facilities, and other such uses to be found around similarly sized airports elsewhere that are more remotely located.

Over the longer term, expected increases in the air transportation of people and goods should create a demand for airport-oriented uses. Requests made recently to the BRA for zoning variances and building permit applications suggest this to be true. Plans for several new hotels are indicated.

2. Airport Development. Logan Airport constitutes the largest external influence on the East Boston area. When acquired by the Commonwealth of Massachusetts in 1890, the future airport site was a tidal flat. Originally the land was intended for expansion of wharf and industrial facilities on the waterfront. More tidal flats were acquired in 1913. Bulkheads were built around them and the process of reclaiming the land from the sea was started by hydraulic dredging. Plans for several piers to be constructed in the area were set aside during World War I. The war indicated the potential of powered flight and the need for aviation facilities to serve the area became apparent. The Commonwealth decided to convert the filled land into an airfield.

The airport was a cinder plot of 189 acres when it was dedicated on September 9, 1923. At first, the airport had two runways, each 1,500 feet long. Now the airport has five, the
shortest of which is used exclusively by general aviation aircraft. The longest runway is slightly more than 10,000 feet long. The field has been enlarged by filling to 2,200 acres. Responsibility for the operation and development of Logan Airport was transferred from the Commonwealth to the Massachusetts Port Authority (MPA) on 7 February 1959.

3. Community Interface. Utilization of over-water approach and departure paths helps to minimize community noise exposure. Runway 33 approaches (or the reverse, Runway 15 departures) over the water, are thus to be preferred. Unfortunately, this creates a simultaneous requirement for takeoffs (or landings) over East Boston. This same problem exists for all runways. From a community noise standpoint, there are several such good-bad combinations, but no good-good combinations available.

Noise abatement operating instructions exist for Logan Airport. Mainly these instructions seek to eliminate overflights in the Bayswater/Saratoga area of East Boston by giving lowest priority to Runway 22L landings and Runway 4R takeoffs. A left turn after takeoff from Runway 22R is specified for the purpose of reducing noise in the City Point section of South Boston.

Noise abatement procedures not withstanding, East Boston residents view the airport with both fear and hatred. Airplane noises are evident in all parts of the community and are severe under the approach zones. These disturbances are
irritants to people and reduce the attractiveness of the community as a place of residence. A second factor agitating residents is airport expansion. The residents feel that expansion of the facilities is gradually devouring the community. The tidal flats, park areas, and beaches along the eastern shore were once accessible to East Boston residents, but today they have been filled in and taken over for airport use. For example, Bird Island Flats are being filled out for the lengthening of two runways. The proposed extension of Runway 15R-33L involves the taking of Memorial Park, while another project requires the taking of Amerina playground. Still a third factor has been the taking of houses -- a development which heightens community agitation and splinters neighborhood ties. Safety is another factor. The presence of oil farms on Chelsea Creek, about one mile from the end of the runway, causes apprehension on the part of nearby residents.

4. Airport Expansion Plans. During the latter half of the 1960s, Massport attempted to obtain public approval for plans to build a regional major airport in the Boston area. As the search for a site progressed, political opposition and public disenchantment with the proposal increased. As a result of this opposition and an awareness that PONYA had been unsuccessful in obtaining approval for anyone of the more than twenty sites considered as the location of a fourth jetport for the New York region during a decade of searching, Massport in 1970
abandoned plans to build a second major airport in the Boston area. Attention was refocused on the alternative of enlarging Logan Airport.

A request for Federal financial assistance was submitted under the Airport and Airways Development Act of 1970 for a project to expand Logan by adding parallel Runway 15L-33R, extensions to Runways 4L and 9, and STOL Runway 15-33 to the airport. Parts of three separate pieces of legislation, and the policies and procedures adopted to implement them, have environmental implications for airport development and required MPA to give careful consideration to a broad spectrum of environmental issues.  

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5 The most relevant provisions are Section 4(f) of the Department of Transportation Act of 1966, Section 102(2)(C) of the National Environmental Policy Act of 1969, and Sections 16(c)(4), 16(d), and 16(e) of the Airport and Airway Development Act of 1970. Under Section 4(f) of the DOT Act, it must be certified that there has been all possible planning to minimize harm to valuable public lands. Section 102(2)(C) of the National Environmental Policy Act is designated to ensure that environmental considerations are given careful attention and appropriate weight in all decisions of the Federal Government. Specifically, this section requires the submission of an environmental impact statement giving consideration to adverse environmental impacts, alternatives to the proposed action, and any irreversible commitments of resources that might be involved. Section 16(c)(4) of the Airport and Airway Development Act directs
The Massachusetts Port Authority engaged several consultants to document the need for airfield improvements at Logan Airport, to develop the best means of meeting that need, and to evaluate the environmental effect that would result. The findings and conclusions of the Port Authority and its consultants are summarized in the "Boston-Logan Environmental Statement.", dated February 24, 1971.

that no major airport development project shall be authorized for receipt of Federal financial aid unless that project provides for the protection and enhancement of the natural resources and the quality of the environment of the Nation; and further, that no project found to have an adverse effect shall be authorized unless the Secretary finds in writing, after full and complete review, that no feasible and prudent alternative exists and that all possible steps have been taken to minimize such adverse effect. Section 16(d) establishes a requirement for public hearings for consideration of economic, social and environmental effects of airport projects, and for certain other purposes, and Section 16(e) establishes criteria and procedures for protection of air and water quality in connection with airport development.

6 Massachusetts Port Authority, Boston-Logan Environmental Statement (Boston, Massachusetts: Massachusetts Port Authority, 24 February 1971). (Mimeographed).
According to the statement: 7

"...the new runway is of highest priority and is urgently needed if Logan is to adequately serve the expanding air transportation requirements of the region."

Traffic demand forecasts indicate that air traffic volumes will exceed the rate annual capacity of the airport before 1975. Since the addition of Runway 15L-33R would increase airfield capacity from its existing level of 368,000 annual movements to 417,000 annual movements, a continuation of adequate air service would be assured.

The Port Authority argues in this statement that operational flexibility of Logan's runway system is severely limited in comparison with other major airports by two principal factors:

(1) only one set of parallel runways is available, and

(2) this single set of parallels is only partially useful for simultaneous operations due to noise abatement restrictions on heavy aircraft takeoffs to the northeast and landings to the southwest (Runway 4L-22R).

7 Ibid., p. 4.
Also, according to the environmental statement, "orientation of the parallels to minimize community noise does not permit over-water approaches and departures."\(^8\) As evident from the discussion in the foregoing section, heavily populated communities are effected by the use of the existing parallel runway system.

"A second parallel runway system," states the Port Authority, "(will) provide overall noise relief through added flexibility of choice in operational runway use and an orientation permitting maximum utilization of over-water approaches and departures. Addition of the new parallel Runway 15L-33R will best satisfy these requirements while providing a runway with approaches further removed from residential area."\(^9\) Improved instrument landing capability and improved safety are also suggested by the Port Authority as justification for the project.

The remainder of the environmental impact statement mainly speaks to the probable impact this construction and subsequent

\(^8\) Ibid. p. 5.

\(^9\) Ibid.
airport operations will have on the natural environment and human living conditions in the vicinity of the airport.

To implement the project, a permit application was made to the U.S. Army Corps of Engineers. The work included dredging, construction of earth and stone dikes, slope protection and drainage appurtenances in three areas contiguous to the existing airport.

As required by Section 102(2)(C) of the National Environmental Policy Act a public hearing was held by the U.S. Army Corps of Engineers on February 26, 1971 to consider the permit application by the MPA for dike and land fill construction required by the project. Opposition to the project was strongly expressed by both public officials and private citizens. Senator Edward Kennedy, for example, appeared to speak in opposition to the project basing his opinion on the project's adverse environmental impact.

As a result of the first public hearing, it became evident that further environmental studies, substantially expanded in depth and scope, would be necessary to answer the questions raised at the hearing. The objectives of this work, as spelled out in the Port Authority's Work Statement of April 16, 1971, were to
develop "appropriate supporting analyses demonstrating that:"

. The plans for improvement of Boston-Logan have been thoroughly reviewed to identify any features of those plans that produce or will produce a significant effect on the environment surrounding the airport.

. Of the various practical alternative courses for improvement of the airport, the preferred alternative represents the best course of action from the standpoint of the effect on the environment, safety, capacity and costs.

. All reasonable steps have been taken to mitigate undesirable environmental effects of the airport development that cannot be avoided.

The consultant's report presenting the findings, with supporting analyses, of their comprehensive study of the proposed Boston-Logan construction program and its environmental consequences was finished in late May 1971.


Portions of the exhaustive study, issued in two volumes and containing many hundreds of pages, addressed issues of air traffic demand, airport capacity, noise, biology, water, air pollution, and economic impact. The combined efforts of six consulting firms contributed to the final documents.

In general, the report favors the expansion of Logan Airport. After summarizing the main findings of the report, Landrum and Brown, Inc., principal consultants to the Port Authority, conclude: "we highly recommend that Massport continue its efforts to improve the existing airport as planned. (As) our report shows, the improved airport presents the best opportunity to realize a reduction of current social impacts. This betterment is a result of noise and air pollution control provided only by the new runway without sacrificing economic benefits to the entire community." 12

A public hearing to discuss the results of the study was scheduled for Saturday, July 10, 1971.

On Thursday, July 8, 1971, Francis Sargent, Governor of the Commonwealth of Massachusetts, addressed a regional meeting of the Metropolitan Area Planning Council. 13 In his address,

12 Ibid. p.2.
13 Opinion expressed by Massachusetts Governor Francis W. Sargent in an address ("The Crisis in Transportation") at a regional meeting of the (Boston) Metropolitan Area Planning Council, 7 July 1971.
dealing with what he termed the "crisis in transportation", Governor Sargent strongly opposed the new runway. The Governor cited as reasons for his opposition: cost, demonstrable failure to meet its (i.e., MPA's) own goals, disruption of present airport operation and an undeniable increase in airport noise impact, especially during the four-year construction period.

Following the Governor's speech, the Port Authority cancelled the impending public hearing.

The Massachusetts Port Authority has not made clear what actions it will take in the future. In his speech, the Governor did not completely rule out the possibility of expanding Logan Airport. He said: 14

"I favor a proposed federal review of the noise impact of such a runway because there are those who contend it can be proven to be not the liability to the environment that today it appears to be, but actually an asset in that its location would not worsen but actually improve noise level problems plaguing the area today. Perhaps. That case is not proven today, certainly -- but let further study go forward. This must be very clear, however: the burden of proof rests with those who favor the expansion of the airport, not those who oppose it."

Whether or not a case will or can be made for runway construction that is capable of winning public support for expansion of Logan Airport, given the existing political climate, is doubtful.

14 Ibid., p. 4.
New York.

1. Surroundings. John F. Kennedy International Airport, "Kennedy", is a major international gateway to the United States. It is located in the southeastern section of the Borough of Queens on Jamaica Bay, approximately fifteen highway miles from 42nd Street, in midtown Manhattan. In addition to the international air service, Kennedy also provides extensive medium and long-haul domestic air service. Furthermore, Kennedy Airport also contains the nation's largest air cargo center.

In close proximity to the airport are sections of Brooklyn, Queens, and the Town of Hempstead in Nassau County. Brooklyn is New York's largest Borough. The population of Brooklyn is about 2.6 million with a density of approximately 33,000 people per square mile and in some areas up to 125,000 per square mile.\(^{15}\) The population of Queens is near two million. Queens is the only one of the four major boroughs whose population increased during the last decade -- by 8.5 percent. The overall density of Queens is less than 18,000 per square mile, approximately that of Boston, but certain areas have a density of 80,000 per square mile. Its residential character and high-income per capita, as compared with the overall average of New York, are characteristics shared by neighboring Nassau County.

Much of central Brooklyn is overcrowded and deteriorating. Its population lacks job opportunities, recreational facilities, and decent and safe housing. Parts of central Queens share these shortcomings. "Partly as a result of this", concludes the National Academy of Sciences in its study of Jamaica Bay and Kennedy Airport, "the development of the areas on the periphery of Jamaica Bay has been accelerating in the last twenty years, despite nuisances, such as the noise of the airport, the pollution of the water and the air, and relatively poor access."\(^{16}\) The major new use of the Bayshore area has been low-density housing.

At the present time, about 700,000 people live in areas near Kennedy Airport that are subject to high-noise exposure. About 120,000 of them live in homes subject to an exposure which should be considered tolerable only for commercial usage in which noise-proofed buildings are used. These large numbers of noise-impacted residents are a result of two factors: the increasing population density in areas surrounding the airport, resulting from housing construction, and the increasing area subject to high-noise levels, caused by more and noisier aircraft operations.

2. Airport Development. Idlewild International, as Kennedy Airport was originally called, opened 31 July 1948. The first years of operation were slow because Newark and LaGuardia

\(^{16}\) \textit{Ibid.}, p. 48.
Airports still claimed most of the attention of the commercial airlines. During the first five years of operation, activity gradually shifted to the field. In the last five months of 1948 there were 5,923 plane movements, by 1952 there were 105,205.\(^{17}\) The Port of New York Authority (PONYA) operates Kennedy Airport under a 50-year lease, signed with New York City, June 1, 1947. The field was originally planned to cover only 1,100 acres. Mid-1953 found the field occupying 4,900 acres and operating five runways varying from 6,000 feet to nearly two miles in length.

Less than a year later, a *New York Times* survey of facilities found the field not ready for jet transports.\(^ {18}\) The greatest problems cited were long distance from downtown business areas, inadequate terminals, awkward handling of passengers and baggage, and weather delays. Inability to foresee air transport growth and unwillingness of proper agencies to provide funds were held to be the major causes. Passenger traffic was reported up six-fold since 1944 but the field's capacities had only doubled. The *Times'* synopsis saw a continued facilities lag curbing industry growth.

Sensitive to these problems, in early 1955 PONYA announced plans for a multi-million dollar airport city to rise

\(^{17}\) *New York Times*, July 31, 1953, p. 21, col. 1.
\(^{18}\) Ibid., May 24, 1954, p. 18, col. 1.
on the framework of Idlewild over the next five years. As a first step, $60 million would be spent to develop a modern passenger terminal facility. Airline housing would be dispersed over a 655-acre landscaped oval instead of being in one terminal. Main developments included a three-story international arrivals building with flanking wing buildings for foreign lines and seven terminals for U. S. lines. Austin J. Tobin, PONYA Executive Director stressed that the design provided flexibility, versatility, expansibility, and adaptability and that there would be no conflict between the flow of baggage, freight, mail and apron services.

3. Introduction of Jet Aircraft: PONYA Meets the Community. The history of the introduction of civilian jet-powered aircraft at Kennedy Airport perhaps more than any other issue, describes the character of the interface between this airport and the surrounding communities. The issue arose in 1955 when PONYA refused to allow a British Comet II jet-liner to land at Idlewild. This action was held consistent with their policy established in 1951 which forbade jet operations at Authority airports until their noise could be reduced.

19 Ibid., February 21, 1955, p. 1, col. 3.
20 Ibid., December 18, 1955, sec. 2, p. 23, col. 3.
The issue assumed major proportions as the Boeing Company prepared the first of its 707 aircraft for delivery. The Port of New York Authority continued to bar jet landings because of noise after attending Boeing 707 demonstrations in Seattle. John Wiley, PONYA Aviation Director, was reported to have stated: "Jet transport operations of the 707 type could not be conducted at Idlewild, LaGuardia, or Newark while the (aircraft's) present external noise characteristics remain unsuppressed." 21

Later, Mr. Wiley defended the ban in a speech saying it spurred companies to develop noise suppressors.

PONYA granted landing rights to the French-built Caravelle jet in April 1957 after it passed noise tests. 22 Summer 1958, The Port of New York Authority granted Pan American permission to operate the Boeing 707-120 on trial runs, assured by consultant's reports that noise would be tolerable. 23 It also scheduled noise tests for the Comet IV. In October, PONYA announced its decision to permit jet operations at Idlewild but imposed strict rules on minimum altitude, runways to be used, and hours of operation. 24

21 Ibid., March 8, 1957, p. 48, col. 6.
23 Ibid., July 17, 1958, p. 53, col. 1.
In August the next year, Queens political and civic leaders held a conference with aviation officials on increasing public complaints on jet noise. They agreed that the problem had intensified in recent months and an increasing number of complaints had been made by borough residents.

The Borough President threatened to close the airport by beginning a sewer repair project that would block access to the airport. An official of the Queens Federation of Civic Councils warned that neighboring residents around the airport had "had it" and wanted immediate action to reduce noise.

The Queens Borough President and other civic leaders appealed to New York Congressional members to curb noise at Idlewild. Representative Emanuel Cellers agreed to write a letter to the FAA asking for action. The letter planned to force the FAA Administrator to say whether his agency had authority to curb airliner noise. In September, 1959, public hearings on aircraft noise were held.

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25 Ibid., August 18, 1959, p. 58, col. 6.

26 Ibid., September 8, 1959, p. 37, col. 8.
A Congressional Representative presided. Queens and Nassau residents and Representatives attended. The chairman read a letter from the FAA Administrator which claimed FAA jurisdiction over the noise problem but said the agency would not act at present waiting for the outcome of studies.

After failing to receive an answer to his September 21 letter to the FAA Administrator asking when action from the FAA could be expected, the Queens Borough President appealed to President Eisenhower. In late November, he asked that the FAA be directed to set up anti-noise rules at Idlewild. "The President," said the Times, "had been advised of the Administrator's earlier advisory to the Borough President that his agency had jurisdiction over noise from planes."

On February 11, 1960, PONYA announced plans to allot $9,700,000 to add 4,150 feet to northeast-southeast oriented Runway 4L-22R. The new length would be the minimum desirable for heavy jets and would make takeoffs to the northeast possible under highly restrictive conditions. This would send planes over the populated areas of central and southern Queens; however, the greater length would enable planes to gain altitude more quickly and would mean no increase in noise levels. Also the extension would permit greater use of the

27 Ibid., November 22, 1959, p. 88, col. 3.
28 Ibid., February 11, 1960, p. 29, col. 6.
runway under adverse wind conditions for over-water takeoffs. The Port of New York Authority also planned an extension of Runway 13R-31L by 1,400 feet to minimize noise in areas to the west and east of the airport.

In May, the FAA proposed the first fully enforceable rules to lessen aircraft noise in the New York area. They compelled jets using Idlewild to select runways headed away from nearby communities whenever possible. PONYA immediately announced that while the FAA move was encouraging the specific rules were inadequate. They did not fix a maximum noise level that a community would have to tolerate and they did not impose stricter rules for nighttime sleeping hours than for daytime.

The Port of New York Authority continued to curb night jet takeoffs and noise levels even though no mention was made in the new FAA rules. In October, the Authority sought an injunction against Delta for jet noise violations. Prospects for a court test of PONYA's legal right to set noise rules dimmed when Delta secured a delay in replying to the Authority complaint. The extension was granted on Delta's

29 Ibid., May 12, 1960, p. 29, col. 1.
30 Ibid., October 27, 1960, p. 39, col. 3.
assurance that, given time, it could demonstrate its ability and willingness to comply with the rules. Observers anticipated that if Delta's performance satisfied the Authority the court action would be stopped.

There was disappointment that a court test of PONYA's legal right to establish rules for aircraft operations would not materialize. "At least one major airline," reported the Times, believed the Authority was way out of bounds in asserting the right to impose such rules."31 It thought the right was reserved to the FAA. This airline was probably not alone. Nevertheless, no one had been willing to challenge PONYA. Most of the 27 airlines operating jets at Idlewild had gone along with the anti-noise rules, whether or not they deemed them legal, at least to the extent necessary to avoid court action. The FAA also avoided challenging the legality of the Authority's rules.

During the summer of 1962, flight patterns were shifted in an effort to cut noise.32 Planes that had been turning left to approach Runways 13L or 31L, among the most used runways, began to turn right. The old left-turn pattern

31 Ibid., November 9, 1960, p. 70, col. 5.
32 Ibid., August 18, 1962, p. 21, col. 7.
brought planes in over southern Queens. The new right-turn pattern brought them in from the direction of Sandy Hook over Floyd Bennett Field and along the Jamaica Bay shoreline.

The change alleviated noise problems for several communities in Queens. Another flight pattern change was also planned. Under this change, planes approaching over Long Island would descent faster to avoid any unnecessary low-level flight. The planes would remain at higher altitudes over the Island before coming down to land.

With this change, the FAA alleviated airplane noise in one part of the city only to find that it had created a new noise problem in another. To a large extent, the problem was shifted from Queens to Brooklyn. Officials of the agency shortly after the change disclosed that the new anti-noise flight pattern had brought complaints from residents of Brooklyn communities.33

Existing community complaints about aircraft noise did little to disrupt developer plans in the vicinity of the airport.

In a 1964 speech before a meeting of Queens business leaders, an FAA official pointed to a number of building

projects near the airport threatening to aggravate aircraft noise problems in the future.34 They were two planned 25-story apartment buildings and a 2,000 home development. These projects were under or near the approach paths along the Jamaica Bay shoreline laid out by the agency two years before to ease noise problems over Queens. The FAA called on city officials to begin a study of land use near the airports in order to bar residential and apartment construction within aircraft approach paths.

FAA warnings did not carry much weight against federally-funded projects. In 1967, the Inwood urban renewal project, delayed because of jet noise, was reactivated.35 Federal action toward approval of the renewal had been halted earlier when an FAA team found the decibel level there would reach the intolerable. An appeal to the White House by a Congressional Representative sympathetic to the city apparently brought the project back to life. In June, the FAA again warned New York City officials, this time against building a Brooklyn housing project.36 Plans called for cooperative apartments for 6,000 families on 145 acres of unused land overlooking Jamaica Bay. The project would be only three miles from the end of two frequently used runways. The FAA advised officials that 156,000 planes had used these

34 Ibid., May 19, 1964, p. 73, col. 1.
runways the previous year and that their flight paths were in the immediate proximity of the proposed housing site. Warning of the noise levels, the FAA said: 37

"Individual reactions resulting from noise exposure of this intensity would likely include vigorous complaints. In addition, concerted group action can be expected."

PONYA noise monitoring boxes were located between the community and airport. An aircraft surpassing the established noise limit when passing over the box made the airline subject to a fine. In October 1967, the Times revealed a five-year old Pan American initiated program to cut jet takeoff noise to acceptable decibel levels. 38 Once over the Authority's noise monitoring box, a ground observer advised the pilot to cut back the engines. Having passed over the box, he resumed his climb full power.

A NASA study of a program similar to Pan American's, showed that the reduction in power dropped the noise level from about 110 to 100 PNdB. When the normal climb was resumed, the noise became higher than it had been before power was reduced. This procedure placed the moment of higher noise directly over the community guarded by the noise monitoring box.

37 Ibid.
38 Ibid., October 20, 1967, p. 49, col. 7.
The added noise did not pass unnoticed by city dwellers. During the next summer, with air traffic at its peak, residents of neighborhoods near the airport picketed Pan American's terminal to protest noise. The demonstrators marched near the front of the terminal building carrying signs saying: "We shall overcome -- but don't come over us," and "Pan Am makes the going grate."

4. Expansion of Kennedy Airport. Beginning in 1957, PONYA made forecasts based on air travel market surveys which indicated a constant and rapid increase in air passengers who would be moving through the region. Nearly 25 million passengers were forecast for 1965 and 45 million for 1975.

The Port of New York Authority's analysis of the 1975 forecast indicated the advisability of an evaluation of the region's airport requirements. Studies were then underway for the complete reconstruction, redevelopment, and modernization of LaGuardia and Newark Airports and the continued improvement and development of Kennedy Airport. Nevertheless, the 1957 forecasts indicated that the capacity of the existing regional system would be unable to serve the future needs of the New


40 The validity of the forecast is evidenced by the record. The Authority airports served 25.8 million air travelers in 1965 and 38.4 in 1969.
Jersey-New York regional airport system.

This evaluation led to the publication in 1959 of the Authority's preliminary report, "A New Major Airport for the New Jersey-New York Metropolitan Area." This report brought public attention to the fact that air traffic demand would exceed the capacity of the regional system and that an additional major airport would be needed to serve the metropolitan area. The report examined fifteen possible sites throughout the New York-New Jersey region and concluded a site in Morris County, New Jersey would meet all requirements for a major new airport.

Efforts by PONYA to obtain political approval for this site were unsuccessful as they have been for more than twenty other specific sites considered during a decade of study and search. Opposition to PONYA proposals for new jetports on several technically feasible sites has originated from the ever increasing public awareness of airport-caused environmental problems.

In 1969, the Authority's proposal to build a fourth jetport to serve the metropolitan region at Solberg in New Jersey became a campaign issue in the gubernatorial election. The successful candidate obtained substantial support by opposing

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41 The Port of New York Authority, Airport Requirements and Sites to Serve the New Jersey-New York Metropolitan Region (1966).
the construction of any additional jetport in the state.

In a statement to the press made shortly after the results of the election were known, Austin Tobin is quoted as saying: 42

"Throughout the campaign we gathered that he is apparently against a fourth airport in northern New Jersey. The Port Authority as a State Agency must follow the policy of the States. As far as we're concerned, therefore, our recommendation for a major airport at Solberg is dead. It would be out of order and an impropriety to attempt to urge any further consideration of a fourth airport there. We'll continue to do the best we can at the three airports to maximize their capacity."

Discouraged also by intense opposition to a fourth jetport among communities on Long Island, in Long Island Sound, and in the mid-Hudson region of New York State, PONYA turned its attention to the alternative of expanding Kennedy Airport by constructing runways in Jamaica Bay. The potential problems of expanding Kennedy Airport into the open area of Jamaica Bay were never underestimated by the Authority.

According to Dorn McGrath: 43

"The central 9,000 acres of tidal marshes and shallows, meandering channels, upland fill, and fresh water ponds have been designated city park land for many years and can be converted to other use only with the state legislature's approval. The same area is crossed by both a major traffic artery and a rail rapid transit line connecting the heavily populated Rockaway Peninsula to

the major employment and service centers of the Bronx and Queens.

In addition, a 1938 project to create the original Idlewild Airport on the margin of Jamaica Bay and a 1964 proposal to expand it into the Bay involved extensive dredging and destruction of at least 5,000 acres of original marshland -- results now carefully recorded and publicized by increasingly active conservation groups. Moreover, the growing hostility of citizen groups and entire communities, because of the obvious effects of aircraft noise associated with flight operations and the apparent contributions of the airport to both air and water pollution in and around the Bay, had already resulted in extensive litigation against the PONYA and in overt political actions to obtain relief by restricting airport operations.

In this context of conflict, PONYA sought the involvement of an objective multidisciplinary group to undertake a study of the environmental impact an extension of the runways at Kennedy into Jamaica Bay would have on the Bay and its surrounding communities. In December 1969, the Authority approached the Environmental Studies Board (a joint board of the National Academy of Sciences and the National Academy of Engineering) about possible Board interest in undertaking the study.

In the past, the Academies have avoided undertaking research and study projects in behalf of non-federal agencies such as PONYA. Ultimately, however, in light of the attitude taken toward the study by The Port of New York Authority and the several expressions of interest by the federal establishment, the Academies authorized formation of a special Environmental Studies Group to undertake the suggested
investigation.

The Study Group examined several possible configurations of runways extending in the Bay from Kennedy Airport. All were considered in relation to the natural ecosystem of the Bay, existing or proposed programs for water quality improvement, recreation and conservation, and present and expected land-usage patterns near the airport.

Four principal conclusions were reached: 4

1. Any runway construction would damage the natural environment of the Bay and reduce its potential use for conservation, recreation, and housing. The degree of this impairment would depend on the size of the area taken for airport extension. A sufficiently large land-taking, such as that proposed by The Port of New York Authority, could cause major irreversible ecological damage to the Bay.

2. It is possible to improve the Bay environment by technological means. Such improvements could be made independent of any airport expansion scheme, but any expansion would increase the economic costs or dilute the benefits of these improvements.

44 McGrath, op. cit., p. 245.
3. The construction of new runways would not significantly reduce the numbers of residents in nearby communities exposed to intense aircraft noise. Major reduction in noise exposure can come only from use of quieter aircraft.

4. The permanent conversion of any estuarine area to airport or other commercial or industrial use would diminish a national environmental asset of great potential value to future generations. Although Jamaica Bay has been altered by man's activities, its ecological viability can be maintained by environmental improvements only if there are no additional major incursions into the Bay.

Additionally, the environmental study group offered eleven specific recommendations for dealing directly with the problems of air-traffic capacity restraints at Kennedy Airport, the provision of an additional regional airport, inadequate building construction standards for noise-exposure zones, the implementation of "quiet-engine" research and development, recreational use of Jamaica Bay and development planning for its bordering community, and a lack of federal policy governing the establishment of essential regional airports.45

Early in February 1971, the final report of the Environmental Studies Board was released. At that time, Austin Tobin announced that the Authority had accepted the report, and on the basis of its recommendations, would not seek to build new runways in Jamaica Bay. With the decision of The Port of New York Authority not to build the proposed runways, thus avoiding the irreversible ecological damage predicted by the Study Group, other alternatives must be explored to obtain a solution to the problem of air traffic congestion at Kennedy Airport. A RAND Corporation report presented to the Authority in August 1969 recommends the development of specialized short-haul airports, capacity rationing, and the development of a V/STOL system as means of obtaining more long-haul capacity. Recently, the Governor of New York, Nelson Rockefeller, endorsed a proposal to expand Stuart Field, an inactive U.S. Air Force base located fifty miles north of Manhattan, into a fourth jetport for the region. A proposal to build STOLports for Manhattan has been the subject of considerable controversy for several years. Most likely, the absence of specific proposals explains the limited adverse reaction that has so far been generated by the other two RAND Corporation proposals. Intense opposition to the Stuart Field proposal has already developed in the nearby community of Newburg and increasing environmental objection is anticipated.

The future need for a second airport to serve Washington had long been established. In 1950, after extensive studies by the former Civil Aeronautics Administration, Congress authorized the construction and operation of a second airfield. Subsequently, $1 million was appropriated to begin the project.

In 1951, the CAA evaluated sites near Annandale, Fairfax, Chantilly, Herndon, Pender, and Burke, all in Virginia and additionally several sites in Maryland. Burke was the first choice and Chantilly second. Land acquisition commenced

47 Background material on Dulles International Airport obtained from James T. Murphy, Acting Director, Bureau of National Capitol Airports. References included:

a. Excerpts from the "Site Selection Study" for an additional Washington Airport.

b. Excerpts from the Dulles Airport Master Plan Report.

c. A noise exposure forecast chart for the area surrounding Dulles Airport.

d. Excerpts from the Comprehensive Plan for the Bull Run Planning District, Fairfax County, pertaining to Dulles Airport.

e. Excerpts from the Comprehensive Plan for the Upper Potomac Planning District, Fairfax County, pertaining to Dulles Airport.

f. Excerpts from "The Air Revolution" and the National Capitol Planning Commission, pertaining to land use and zoning surrounding Dulles Airport.
in the Burke area. The next year, the CAA sought a supplemental appropriation from Congress for $1.6 million to cover additional land purchases and engineering design costs. The resulting hearing brought out strong and well organized opposition to the Burke site and the appropriation request was not granted. Additional studies were conducted during the years 1953 to 1955, but no additional appropriations were forthcoming. Land acquisition was halted after 1,050 acres has been obtained.

Following Senate Commerce subcommittee hearings in June, 1955, the CAA prepared a report again recommending the Burke site. The subcommittee's report suggested that a construction program be presented to Congress keyed to provide usable airport facilities there by January 1959. A request for $34.7 million then was turned down by the Congress when opposition to the Burke site continued strong at the July 1956 Senate hearings.

After several additional Congressional hearings, $12.5 million was appropriated for necessary expenses for a new airport in August 1957. None of the money was to be expended until after President Eisenhower recommended a site. Special Presidential Assistant, E. R. Quesada retained a consulting firm which reported that Chantilly offered the best long-range solution to Washington's aviation needs. It was found to have superior airspace potential, providing for full development of airport capacity. It appeared that impact on the local community would be lightest at Chantilly,
and ground conditions lent themselves best to economical airport construction and expansion.

Mr. Quesada recommended Chantilly and the President endorsed this choice in his report to Congress. Land acquisition started in January 1958 for what is now Dulles Airport (Figure II-5). Eventually the site totaled 10,000 acres.

The airport has two parallel north-south runways, 11,500 feet long, separated by 6,700 feet and overlapping 50 percent of their lengths. The west northwest-east southeast runway is 10,000 feet long. If traffic requires a fourth runway it will be the same length and parallel to the first WNW-ESE runway with 3,000 feet separation and 50 percent overlap.

Considerable care was taken by planners to make the airport a good neighbor. Enough land was acquired to keep airport boundaries a reasonable distance from the runways. No standing timber was removed from a belt extending 1,000 feet inward from the airport boundaries and additional trees were cultivated to dampen aircraft noise. The FAA also worked with local government planning bodies to obtain compatible zoning around the airport. The FAA recommended that the area immediately surrounding the airport be restricted to uses of an industrial nature and that in the high-noise zones under flight paths, no residential development be permitted.
The success of these efforts has not been total. In 1965, Arthur D. Little investigators reported that:

"In spite of the vast amount of land acquired for the airport and an attempt by the Federal Government to induce local jurisdictions to zone the surrounding land for compatible activities, subdivisions have developed near the airport."

Summary: The Community Airport Relationship

Information revealed (in the three case studies) about the character of the community-airport interface can be summed up as follows:

1. Noise exposure is the most serious problem affecting the community-airport relationship. The everyday operation of Logan and Kennedy Airports is the subject of widespread public controversy mainly because of the noise generated. Planning for Dulles Airport was significantly conditioned by the requirement that present and future community noise exposure be minimized.

2. Noise exposure has created extensive citizen protest. This protest has grown in strength, pervasiveness, and effectiveness in direct proportion to the emerging awareness of this and other airport environmental problems. Observations in Boston showed that within those communities exposed to high levels of noise, intense local resistance was encountered in attempts

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to expand Logan Airport. Powerful political figures, including the Governor and Senior Senator, sided with the opposition. The National Academy of Sciences study of Kennedy Airport and Jamaica Bay concluded that unacceptable environmental conditions would result if the airport were allowed to expand into Jamaica Bay. Noise exposure was cited as a significant factor influencing this decision.

3. Evidence assembled in these cases testifies to the validity of the hypothesis that future airport development is contingent upon improvement in the present community noise exposure problem.

The possible validity of this hypothesis has profound implications for the future of civil aviation. No major new construction at an existing airport or development of new airports is likely to obtain public and political approval as needed until and unless some solution to the noise exposure problem has been found. As a further consequence, this evidence infuses the objective of this dissertation -- to develop a systematic approach to the resolution of the airport noise problem -- with an especially critical significance.
Figure II-1
LOGAN AIRPORT AND VICINITY
EASTERN MASSACHUSETTS
Figure II-2
EAST BOSTON AND VICINITY
Figure II-3
LOGAN AIRPORT NEIGHBORHOOD
PLACE NAMES AND ZONE NUMBERS

CHELSEA

REVERE

ORIENT HEIGHTS (B-5)

Bayswater (B-1)

Pleasant Park (W-4)

Court Park (W-1)

Cottage Park (W-2)

INNER HARBOR

LOGAN AIRPORT

INNER HARBOR

EAST BOSTON

Jeffries Point (B-6)

Eagle Hill (B-4)

SOUTH BOSTON

CASTLE ISLAND 0 .5 1 MILE
Figure II-5

DULLES INTERNATIONAL AIRPORT AND VICINITY

Scale: 1 inch = 5 miles
CHAPTER III

NOISE AND ITS MEASUREMENT

What is noise? Noise is often described as sound without value, but in order to understand the problems of noise and its control, it is first necessary to understand how sound is produced and how it is measured. This chapter is intended to provide the reader both a systematic exposition of basic acoustical terminology and an intuitive grasp of the techniques used to measure and interpret exposure to aircraft noise.

Acoustic Terminology

A sound source produces very small periodic variations in the normal atmospheric air pressure which, upon reaching the eardrums, are translated by the human hearing mechanism into the sensation called sound. These pressure changes, the magnitude of which is called the pressure amplitude, can also be detected and measured with a sound pressure level meter.

The rate at which sound energy is transmitted to a surface, per square centimeter of surface is called the intensity of the sound. If $P$ is the root-mean-square pressure amplitude of the sound, the intensity $I$, in watts per
square centimeter, is given by the formula:

\[ I = 2.37 \times 10^{-9} \, \text{p}^2 \]

The human ear can discern sound whose intensities are as small as \(1 \times 10^{-16}\) watts per square centimeter, and it responds without damage to sounds \(10^{12}\) times as intense. In contrast, the human eye responds to a light intensity range of only \(10^5\).

Partly because of the very large range of intensities over which the human ear responds, a logarithmic rather than linear scale is used for the expression of acoustic intensities, and intensities are measured relative to the intensity at the threshold of audible sound, namely \(10^{-16}\) watts/cm\(^2\). The unit is the decibel and the intensity level, IL, is then defined by:

\[ \text{IL} = 10 \log \frac{I}{10^{-16}} = 10 \log I + 160 \]

If the intensity of a sound is \(10^{-16}\) watts/cm\(^2\) (the faintest audible sound), its intensity level is zero decibels. A sound whose intensity is \(10^{-15}\) watts/cm\(^2\) is ten times as intense as this threshold, and its intensity level is ten decibels (commonly abbreviated dB). While listening to a

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1 The formula applies for air at standard conditions: temperature at 20°C and barometric pressure at 760mm of mercury. The units of measurement are usually metric, by convention, and are either watts or dynes.
sound whose intensity is gradually increasing, the sensation called loudness also increases, but loudness is not proportional to intensity. Rather, the sensation of loudness doubles with each ten dB increase in intensity level. Therefore, the 60 dB sound is about four times as loud as the one of 40 dB. 2

While the logarithmic decibel scale keeps the numbers to a manageable level, some problems arise with the addition of sound levels from two different sources. Consider, for example, two sound sources each producing 90 dB. The total sound intensity produced by the two sources is twice that for a single source. However, the sound level generated by the two sources is 93 dB, not 180 dB. Regardless of the level, doubling the intensity of a sound results in a 3 dB increase in the sound level.

For an aircraft, the overall noise level is actually the sum of the noise produced by many individual noise generating mechanisms in the aircraft. If each individual sound source could be isolated and measured, their logarithmic sum would be the total noise produced by the aircraft. Lindley has plotted the

additive effects of two sound sources.\(^3\)

His work shows that if, for example, the exhaust jet had a value of 90 dB, the effect of the two together would be only 100.5 dB. This means trying to quiet the engine by reducing compressor noise would accomplish little. The predominant individual noise source roughly defines the noise level for the total system.

Since the sound intensity decreases as the square of the distance from the source, doubling the distance between the source and the listener results in a six dB decrease in the sound level.

For example, if an aircraft produces a 98 dB noise level at a distance of 1,000 feet, the noise level would be 92 dB at 2,000 feet and 86 dB at 4,000 feet.

In addition, there is atmospheric attenuation and attenuation due to the proximity of the transmission path to the ground, where applicable. Atmospheric attenuation is dependent on the frequency of the sound, wind speed and direction, turbulence, humidity, and temperature. Figure III-1 shows some typical ground attenuation factors.

Although the loudness sensation doubles with each ten dB increase in intensity for sounds whose frequencies are close to 1,000 cycles per second, this relationship does not hold true across the entire frequency range of audible sound. In Figure III-2, which is a graph of the auditory area of a person with good hearing, contours of equal loudness have been plotted. The number of each curve is the intensity level of the 1,000 cycle per second tone used for comparison for that curve. For example, the 60 dB contour shows that an intensity level of approximately 70 dB at 100 cycles/sec. is equally as loud as a 60 dB level at 1000 cycles/sec. The bottom curve for zero loudness is the threshold of hearing and represents the intensity level of the faintest sound of that frequency which can be heard. The top curve represents the threshold of pain above which the sensation changes from one of hearing to discomfort or pain. The area bounded by these two curves represents the range of audible sound in frequency and intensity.

Sound measuring instruments exist which can selectively discriminate against high and low frequencies in accordance with the equal loudness contours in Figure III-2. Using such an instrument, the results are expressed in decibels on the A-weighted scale (abbreviated dB (A)). In studies of aircraft
noise, the scale most often used is the Perceived Noise Level (PNdB).\(^4\) Intensity levels for a number of familiar sounds, expressed in decibels on the PNdB scale, are shown in Figure III-3.\(^5\)

Another, more complex, sound index has been suggested which expands the PNdB method to account for those human response characteristics which involve discrete frequency tone phenomenon and duration annoyance. This modified representation is called the Effective Perceived Noise Level scale (EPNdB), and it contains both weighing factor and a duration weighing factor. It is defined by:

\[
\text{Effective Perceived Noise Level (EPNdB)} = \text{PNdB} + \text{Tone Factor} + \text{Duration Factor}
\]

A more detailed analysis of the composition of noise as a function of frequency is necessary because people react differently to a high-frequency squeal than to a low-frequency roar. This method is, thus, able to account for the greater public annoyance experienced for the whine of a


\(^5\) The PNdB scale was developed in 1959 for The Port of New York Authority, by the Cambridge, Massachusetts consulting firm of Bolt, Beranek, and Newman.
compressor than for the louder (sound pressure level) jet exhaust. Finally, duration is important because the more time an event consumes, the more it can contribute to community response.

Measurement of Community Response

Noise Exposure Forecasts. The Federal Aviation Administration and the military services have recognized the need for procedures to describe the noise exposure from airport operations in objective terms and have sponsored considerable work along these lines. Several procedures have been developed to describe the airport-community noise exposure situation. In general, these procedures reflect experience from:

- studies of neighborhood reaction to noise at many commercial and military airports,
- studies of measured noise data of current aircraft and estimated noise data for anticipated aircraft,
- performance data on the takeoff and landing characteristics of present and anticipated aircraft, and
- the effects of various types of noise on the living and working environments in the airport vicinity.

This dissertation discusses the airport-community noise situation in terms of Noise Exposure Forecast (NEF)
The NEF methodology starts with information about the noise associated with an individual aircraft activity, based on a series of measurements. This information is then supplemented by operational information, consisting typically of the flight paths that the aircraft take, the time of day at which these occur, and the number of flights of each aircraft type. The role of each of these inputs in determining noise exposure may be seen from simple qualitative arguments. If the aircraft follows a flight path permitting it to climb rapidly after departure, it will produce a smaller noise exposure than the same aircraft operating under similar conditions but climbing less rapidly. Time of day is important because experience consistently indicates that noises occurring during the late evening and early morning hours produce a greater annoyance in the community than noises occurring at other times of the day. Finally, the number of events is important because the more frequently an event occurs, the more it can contribute to community response.

The NEF procedure indicates that there exists a possible trade-off relationship between the noisiness of an event and the frequency of its occurrence. A very noisy event that

^6^ Although this dissertation uses PNdB in the discussion of aircraft noise, dB(A) can be approximated by subtracting 13dB from the measured PNdB value.
occurs infrequently may be less important than a less noisy event that occurs more frequently.

NEF contours are intended to represent long-term average pictures of the noise exposure. Therefore, the operational information utilized in developing the contours is based on conditions averaged over an entire year. Noise measurements made at any one time (say, over a period of a few days) may be thought of as representing a "snapshot" of the situation at that time, rather than the long-term average of the NEF contours. Thus, the year-average picture of the NEF contours cannot be compared directly with short-term "snapshot" noise measurements, although such noise measurements do serve as the starting point of the description of noise exposure.

Interpretations. The NEF procedure is basically a methodology for estimating a quantity of noise exposure that would result from certain assumptions about aircraft operations. However, the computed numbers have little value unless some meaning is attached to them. The following material presents the relationship between various land uses and aircraft noise exposure expressed in terms of Noise Exposure Forecast values.  

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No one set of interpretations can be expected to apply in complete detail to all airport neighborhood communities. There may be, for example, considerable variability in people's reaction to noise or their assessment of a given noise environment. In addition, any given land use category may incorporate a range of activities having varying sensitivities to noise. Further, there may be a considerable range in noise insulation of buildings that might be found suitable for a given work activity. Taking into account such variables, compatibility descriptors can be used as guides to land use planning but cannot be blindly applied as inflexible criteria.

Figure III-4 gives noise compatibility descriptors for a range of NEF value for different land uses. The choice of the descriptor is governed by the NEF values describing the noise exposure. The meaning of the descriptors is shown in Table III-1.

From Figure III-4, note that, for most land uses, the descriptor for the lowest NEF values correspond to the notation "satisfactory with no special noise insulation requirements required for new construction." This notation indicates that on the basis of case history experience with comparable noise exposures, there should be no major adverse effects

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from aircraft noise although some complaints may occur and noise may occasionally interfere with some activities. The descriptors corresponding to higher levels of noise exposure generally define a range of noise exposures in which new construction or development should not be undertaken unless an analysis of noise requirements is made and needed noise insulation features are included in the building design and site development. For more extreme noise exposures, many of the land uses are assigned a descriptor saying that new construction or development should not be undertaken.

Application of Noise Measurement Procedures

In 1964, pursuant to an FAA contract, the firm of Bolt, Beranek and Newman developed guidelines "that may be useful to land use planners" with regard to aircraft noise.9 The FAA reproduced the report for interested public parties desiring knowledge on the "latest state-of-the-art in calculating noise ratings."10 The Report describes a procedure for predicting average community responses to engine noise generated by aircraft operations. The procedure is called

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10 Ibid.
the Composite Noise Rating (CNR). The Report, however, carried the following disclaimer: "...the contents of this report reflect the views of the contractor...and do not necessarily reflect the official views or policy of the FAA. This report does not constitute a standard, specification, or regulation."

Widespread use has been made by airport planners of the CNR procedure described in the report. Despite the FAA disclaimer, they (the FAA) have encouraged the use of the procedure in the evaluation of compatible aspects of land use with respect to aircraft noise associated with existing and proposed airports.

It was later found desirable to sponsor further research to refine and augment the CNR method to accommodate needs for a more exacting descriptor of aircraft noise exposure. The result was the Noise Exposure Forecast method discussed in the previous section, developed by Bolt, Beranek, and Newman under contract to the Federal Aviation Administration.

NEF contours, as indicated in the previous section, depict land areas having different degrees of noise exposure which influence the land use and the reaction of people residing in the given land area. In effect, the NEF procedure was an updating of the CNR work accomplished earlier by the same firm.

11 Ibid.
The NEF methodology, like the CNR, has at present no particular official sanction. As with the CNR before, there have been no references to the use of the NEF methodology as an appropriate means for evaluating aircraft noise impact. A recent reference is, for example, a FAA order dated 7 December 1970 which states that one acceptable method of analysis for studying the effect of aircraft noise levels on people is the Noise Exposure Forecast. 12

But, as with the previous report, the FAA stated "... this report reflects the views of the contractor and does not necessarily reflect the official views or policy of the FAA. The report does not constitute a standard, specification, or regulation." 13

The Federal Aviation Administration maintains that it "does not have authority to promulgate standards for land usage in the vicinity of airports." 14

12 Federal Aviation Administration, "Interim Instructions for Processing Airport Development Actions Affecting the Environment," FAA Order 5050.2 (Washington: The FAA, 7 December 1970). (Mimeographed.)


Herein lies a dilemma that hits at the root of the issues related to noise alleviation. Namely, if the Federal Government is to pursue an active role in alleviating noise by engine noise reduction (engine modification), implementation of airport procedural changes, and development of compatible land use criteria, then must it establish a standard by which to positively measure the effect of such an action?

As the identification of the level at which a systematic approach to the alleviation of aircraft noise exposure is to be pursued is essential to the definition of such program, the investigation in the following chapters will provide an answer to this question.
Figure III-1

ATTENUATION DUE TO TERRAIN EFFECTS

Auditory area of a person with good hearing. Equal loudness contours are shown plotted against intensity level and frequency. The bottom curve, for zero loudness, is the threshold of hearing, while the top curve represents the threshold of pain.

Figure III-3
AMBIENT AND SPECIFIC NOISE LEVELS

THRESHOLD OF PAIN

130
SST Sideline Noise
(1,500 Ft.)

120
Rock and Roll Band
(Peak)

110
Jet Transports

100
Diesel Freight Train
(40 mph 200 Ft.)

90
Helicopter in Cruise
(1,000 Ft.)

80
Heavy Downtown
Commercial Traffic

70
Passenger Car
(50 mph 200 Ft.)

60
Industrial Area

50
Urban Residential
Area (Day)

50
Quiet Suburban
Area (Night)

40
PNdB

**Figure III-4**

**LAND USE COMPATIBILITY CHART FOR AIRCRAFT NOISE**

<table>
<thead>
<tr>
<th>LAND USE CATEGORY</th>
<th>COMPATIBILITY CODE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NOISE EXPOSURE</td>
</tr>
<tr>
<td></td>
<td>FORECAST VALUE</td>
</tr>
<tr>
<td></td>
<td>20  25  30  35  40  45  50  55</td>
</tr>
<tr>
<td>Residential-</td>
<td></td>
</tr>
<tr>
<td>Single and Two Family Homes, Mobile Homes.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Residential-</td>
<td>A</td>
</tr>
<tr>
<td>Multiple Family Apartments, Dormitories, Group Quarters, Orphanages, Retirement Homes, etc.</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Transient Lodging-</td>
<td>A</td>
</tr>
<tr>
<td>Hotels, Motels.</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>E</td>
</tr>
<tr>
<td>School Classrooms, Libraries, Churches, Hospitals, Nursing Homes, etc.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Auditoriums, Concert Halls, Outdoor Amphitheaters, Music Shells.</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Sports Arenas, Out-of-Door Spectator Sports.</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Playgrounds, Neighborhood Parks.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Golf Courses, Riding Stables, Water-based Recreational Areas, Cemeteries.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Office Buildings, Personal, Business and Professional Services.</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>B</td>
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<tr>
<td></td>
<td>E</td>
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Figure III-4 (Continued)

<table>
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<tr>
<th>LAND USE CATEGORY</th>
<th>COMPATIBILITY CODE *</th>
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<tbody>
<tr>
<td></td>
<td>NOISE EXPOSURE FORECAST VALUE</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td>Commercial- Retail, Movie Theaters, Restaurants.</td>
<td></td>
</tr>
<tr>
<td>Commercial- Wholesale &amp; Some Retail, Industrial/Manufacturing, Transportation, Communications and Utilities.</td>
<td></td>
</tr>
<tr>
<td>Livestock Farming, Animal Breeding.</td>
<td></td>
</tr>
<tr>
<td>Agriculture (Except Livestock Farming) Mining, Fishing.</td>
<td></td>
</tr>
</tbody>
</table>

* Corresponding Land Use Descriptors Are Listed in Table III-1.
<table>
<thead>
<tr>
<th>Compatibility Code</th>
<th>Land Use Descriptors</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Satisfactory, with no special noise insulation requirements for new construction.</td>
</tr>
<tr>
<td>B</td>
<td>New construction or development should generally be avoided except as possible infill of already developed areas. In such cases, a detailed analysis of noise reduction requirements should be made, and needed noise insulation features should be included in the building design.</td>
</tr>
<tr>
<td>C</td>
<td>New construction or development should not be undertaken.</td>
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<tr>
<td>D</td>
<td>New construction or development should not be undertaken unless a detailed analysis of noise reduction requirements is made and needed noise insulation features included in the design.</td>
</tr>
<tr>
<td>E</td>
<td>New construction or development should not be undertaken unless directly related to airport-related activities or services. Conventional construction will generally be inadequate and special noise insulation features must be included. A detailed analysis of noise reduction requirements should be made and needed noise insulation features included in the construction or development.</td>
</tr>
<tr>
<td>F</td>
<td>A detailed analysis of the noise environment, considering noise from all urban and transportation sources should be made and needed noise insulation features and/or special requirements for the sound reinforcement systems should be included in the basic design.</td>
</tr>
<tr>
<td>G</td>
<td>New development should generally be avoided except as possible expansion of already developed areas.</td>
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CHAPTER IV

THE EFFECTS OF JET AIRCRAFT NOISE

Noise has been identified as the most serious problem arising from airport operations. The objective of this chapter is to describe some of the many ways in which this problem has direct and indirect effects on human beings, environmental quality, and civil aviation.

The Effect of Noise on People

Fundamental to the questions of aircraft noise pollution in the vicinity of the airport is its effect upon man. Primarily, noise generates concern because it is harmful to people. Intense sound can cause physical damage to buildings, plants, and animals, as well as man. It is the potential hazard to health of urban residents which is most important here.

Experiments and observations have established that noise is capable of producing physiological effects.¹,² Prolonged or


repetitive exposure to noise of certain intensities will produce hearing loss in varying degrees or impairment by direct physical damage to the human hearing mechanism. Evidence from medical records of this type of physiological injury are the basis for the industrial noise limit criteria in health and safety laws and regulations. More recently, scientific investigative efforts have sought to extend understanding of human chemical and physiological reactions to noise. Noise above 75 dB are known to produce a number of temporary changes in the chemical balance and physiological state of man.

3 Cohen, op. cit.


Psychological effects of noise are less well documented. Experiments have been conducted to determine the "complaint" response of sample populations to various types and intensities of noise. Data from such tests have been used to project expected reaction of larger populations to noise. Such extrapolations have to be held suspect. Human adaptability is well known. Man can adjust to a wide variety of conditions -- fortunately, for his emotional stability and physical survival. Psychologists believe, however, that this adaptation is taking its toll in the unconscious part of the human psyche or involuntary nervous system. In precisely what way and how much noise affects people in this way is not yet clear. Research exploring and monitoring psychological forces and physiological conditions should yield new information on the unconsciously disruptive effects of noise. In the meantime, psychology and psychiatry do seem unanimous in their opinion that noise is registered in and affects the unconscious mind and central nervous system as an irritant or disruptively in


some other way. Indeed, Professor Melville Branch has observed: 9

"The practical consequence of the state of scientific research relating to hearing is that the adverse effects of noise cannot correctly be limited to damage which can be demonstrated beyond any reasonable doubt."

These unconscious effects, together with the human acceptance of our adjustment to unwanted conditions, reluctance to complain or not bothering because it is believed useless, or general distrust of the governmental establishment, suggest that the lack of registered complaints is insufficient evidence for assuming little or no costs to human health and efficiency are being incurred. Not only must physiological reactions not yet fully understood be considered, but also consciously unperceived psychological effects even less well understood.

The Effect of Aircraft Noise on Human Activities

The size of the aircraft noise problem has been increasing annually. The International Civil Aviation Organization (ICAO) citing data from a study by the

U.S. Department of Housing and Urban Development indicated that:

"...in the 21 U.S. large hub areas, 28 of the 36 air carrier airports are presently more than 50 percent impacted, with 43 percent of these airports 100 percent impacted (completely surrounded by high-density development). Projecting sample data, HUD calculates that for these 28 airports alone there are some two million dwelling units within 100 CNR contours. To these affected structures, HUD notes, must be added, schools, churches, and theaters, also greatly affected, and stores, industrial establishments, factories, etc. affected to a lesser degree."

Eighteen of these airports are located within 10 miles of the central business district of the major city it serves. Although highly accessible, high land values constrain outward expansion. By 1980, an increase of 143 percent in scheduled air carrier operations is forecast for all of the 21 large hubs studied.

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11 These figures represent only the 28 major U.S. hub airports. To these must be added the noise-affected dwelling units and structures surrounding the other 496 commercial hub airports in the United States.

12 ICAO, loc. cit.
Commenting on these facts in a recent AIAA paper, Dorn McGrath stated:13

"There is a strong correlation between increased air traffic volumes and community consciousness of the airport itself, and thus, as air traffic intensifies at an encircled airport, the noose of community objections within which it must operate draws tighter every year."

Visible noise effects on critical human activities create this consciousness.

McGrath studied its effect on education:14

"Aircraft noise in the environment of communities near Los Angeles International Airport has become severe enough to require the closing of two public schools. The specific effects of the noise are varied, ranging from pupil and teacher fatigue to outright disruption of classroom teaching. It is difficult to measure or place a value on fatigue and irritability, both well recognized effects of environmental noise, but the inequities of disrupted classroom sessions can be understood by rudimentary quantification. In Inglewood, California, located just east of Los Angeles International Airport, a campus for public elementary and intermediate schools lies between the approach paths to the airport's two main landing runways. On a typical day, approximately 4,000 children are attending school on this campus, which is approximately one-half mile from the end of these airport runways. Because of prevailing winds, essentially all aircraft landing at the airport approach from the east and pass directly or nearly over the schools. Many of the overflights produce a total eclipse of communications in the classrooms, even with the windows closed. This intrusion of aircraft noise has resulted in a pedagogical approach known somewhat bitterly among the teachers and school officials as "jet-pause teaching."


14 Ibid.
From this example of noise cost, aggregate effects can be identified:15

"Noisy aircraft, reflecting only half of the more than 320,000 commercial operations at the airport each year, pass over Inglewood schools about once every three minutes on a typical day on approaches to the airport; this means that every 50-minute class session may be interrupted by noise sufficient to eclipse verbal communications in the classroom about sixteen times. The typical duration of each such communications eclipse is about twenty seconds. Thus, a total of more than five minutes or about ten percent, is lost to each class. With six classroom periods each school day, nearly 32 minutes of teaching time are lost for each pupil; this represents nearly eleven percent of each day devoted to tolerating the noise of passing jets and other aircraft. It translates into the loss of more than an entire school day every two weeks for several thousand pupils in the Inglewood Unified School District."

Time lost is only one cost. Teacher turnover in the school system is another. Additional construction (and, therefore, tax) costs to sound-condition classrooms against noise interference must be added. And the rest of the community located within the zones of high noise exposure require these cost factors be multiplied over and over: for homes, for hospitals, for businesses and other noise-sensitive land uses.

The air transportation industry has been slow to recognize the effects of airport noise on environmental quality. Efforts to undersell the impact of aircraft noise and a tendency to cavalierly dismiss complaints about it have for many years characterized the general attitude of the industry. For example, an aviation industry technical committee, "set up to

15 Ibid.
protect the public from excessive aircraft noise" said in 1958 while arguing why the new Boeing 707 should meet the PONYA noise requirements: 16

"There is a good possibility that after becoming accustomed to the difference between the Boeing noise and conventional aircraft noise, many people residing near the airport will prefer the jet noise."

Eight years later, a NASA study on the optimum use of land exposed to aircraft noise reached this conclusion: 17

"It is clear that to a substantial part of the public, particularly to those who are less sensitive to noise than others, the advantage of being close to air transportation and to the commercial activities generated by an airport, adequately compensates for the attendant noise.

Clearly at odds with these platitudes is the present magnitude and intensity of complaints from those exposed to the noise. In response to these complaints, most aviation officials have denied any responsibility and passed the blame on to others. Industry advocates typically argue that any fault lies with the home buyer who purchased in an area known for low altitude aircraft operations, and resolve the aircraft or airfield operator of responsibility. Background material on airport development does not substantiate this line of reasoning. The theory supposes that the airport preceded the residents. In Boston, the

16 New York Times, 4 September 1958, p. 54, col. 2.

community of East Boston presently inundated by jet noise was thriving and prosperous when clipper ships dominated the seas. In New York, both to the east and west of Kennedy Airport, established communities preceded airport development. Only to the north, under the approach path to Runways 22R-4L and 22L-4R was the land undeveloped. Originally, this area was zoned primarily for light industrial use. Compatibility with the airport seemed relatively assured. Pressure for residential development later resulted in zoning changes permitting home building. Thus, Kennedy Airport's "jet-alley" was born.

The name, jet alley, indicates one aspect of the aircraft noise problem. Jet noise is the major objection of persons near the airport. Many purchased homes near airports before the widespread use of jet aircraft. Later jet operations reached frequencies sufficient to be disruptive. Additionally, changes in approach paths have subjected unsuspecting and unprepared airport neighbors to high noise levels.

Recently, attempts have been made to compensate persons in the airport environs for the costs resulting from their exposure to aircraft noise. The assessed valuation of some property adversely affected, for example, has been lowered, giving tax benefits to the owners. Direct payments for damage and disruption have been made in other cases. The actual cost of aircraft noise as it effects those living near the airport
cannot be measured in dollars and cents alone. Costs in terms of people are incalculable. People do not want to have their communities destroyed and be forced away from friends, neighbors, and familiar surroundings. Neither do they wish in their attempt to preserve these values to any longer absorb this externally imposed cost or to pay for its resolution which they feel is the responsibility of the aviation industry. So serious has the present confrontation between communities become that further prosperous development of commercial aviation is threatened.

The Effect of Noise on Civil Aviation

The nature of the noise problem is simply put. Noise from aircraft has been increasing over the last fifteen years. Not only do engines today produce more noise, but also there are more noise events (aircraft operations). The effective political power of people subjected to aircraft noise has been increasing and will probably continue to increase. In addition, the number of people affected by noise has been increasing.

One consequence of noise in this context is the many ways in which it has direct and indirect effects on civil aviation. Some of them are discussed below. For a proper perspective, it is important to relate the various elements of the noise issue on a quantitative basis. This discussion considers various factors and alternative actions to show noise costs are sizable from a dollar standpoint.
Airports Require More Land. One way to reduce the noise impact is to provide noise buffers by acquiring more land in airport approach/departure areas. There are two main consequences of using land as a noise buffer. First, the additional land is a cost to the aviation system. Second, the noise buffer land has an opportunity cost to the community; that is, there are presumable uses for the noise buffer land which could serve the community better were it not for the aircraft noise.

It is possible to estimate what the dollar cost of acquiring land as to a noise buffer zone would be. The area of land encompassed by the 100 PNdB takeoff contour of a long-haul, four-engine, civil jet is approximately 7,000 acres; the area of land encompassed by the 110 PNdB contour is approximately 600 acres. Assuming a typical airport has eight runway ends, a ten PNdB noise reduction would "relieve" approximately 51,000 acres. To buy this acreage, assuming we were establishing an airport, say, 30 miles from a major city, would cost approximately $350 million at an assumed cost of "underdeveloped" acreage at $7,000/acre. The saving associated with an assumption that three airports were involved would equal the billion dollars sometimes heard as an estimate to "quiet" the current civil aviation jet fleet. Land costs obviously become even more critical closer to the city;

18 Using Bolt, Beranek, and Newman's Technical Report Appendix A, October 1964; Contour Set 1; assuming runway length = 12,000 feet.
therefore, the viability of an intercity STOL system is greatly affected. If we assume a STOL aircraft will make the noise of an F-27, the area encompassed by the 100 PNdB contour is approximately 620 acres; a ten PNdB reduction would "relieve" approximately 1,000 acres per STOLport (assuming one runway). Further, assuming that the location of the STOLport to be approximately 2 miles from a CBD, the cost saving involved would amount to $650 million at an assumed land value of $650,000/acre.

Airport Capacity is Reduced. Noise has reduced and will continue to reduce airport capacity in three ways. First, noise curfews (typically, no jet operations from 11:00 pm to 7:00 am) limit the number of hours the airport can be used, with the additional resulting adverse effect of adding the nighttime traffic demand which may ideally operate at night, as with certain cargo activities, to the daytime traffic which often has peak demand problems. Second, it is common to restrict runway usage because of noise (i.e., usage of certain runways exposes more people to noise than others). Thus, the utilization of existing or potential runways on an airport is reduced. Third, flight path restrictions in the terminal area airspace generally make certain portions of that airspace unusable and, thus, further reduce airport capacity and often increase aircraft travel time/cost.

19 Using Bolt, Beranek, and Newman's Technical Report Appendix A, October 1964; Contour Set 1; assuming runway length = 2,500 feet.
Imposed use of runways and airspace causes aircraft operating delay directly attributable to noise at many airports. The cost of this delay can be quantified. It is conceivable that an airport's capacity could be reduced by 20 percent due to noise restrictions and as such, assuming an airport with a loss in capacity from 500,000 to 400,000 with an annual demand of 450,000, the increase in annual aircraft delay cost is estimated at approximately $1 million. While this value is lower than other cost factors considered, it must be realized that this particular item is applicable to some degree at all existing airports where noise abatement procedures have been or will be implemented.

**Existing Airports are Threatened.** At the same time as aircraft noise intensity and noise events have been increasing, cities have been enveloping airports. The result is that the continued existence of an established airport is threatened at the very time it needs to grow. Indeed, increased activity will generate more noise and hence more pressure to reduce and even prohibit airport activity.

**Suitable Locations for New Airports Cannot Be Found.** As the nation grows and evolves new patterns of distribution of population and industry, new airports will be needed if aviation is to offer a viable air transportation alternative in a balanced system. Even with increased airport size to accommodate
noise buffers, community reaction to potential airport noise is such that suitable new locations will be difficult to find.

The effects of aircraft noise are not confined to the most immediate airport neighbors, but also cause appreciable reaction in more distant communities along flight paths. Thus, large numbers of citizens can see themselves as potential airport neighbors or potential residents under heavily used flight routes.

Consequently, airports have been and will be established in locations less convenient to the user and as such the travel time/cost to get to and from the airport will be increased. While not trying to establish a fact for all airports, one set of probable statistics were developed which showed that the annual cost increase to vehicular users of an airport handling ten million enplaned passengers due to an average ten mile "user to airport" increase amounted to $30 million.20

**Short-Haul Aviation Growth is Impeded.** As mentioned earlier, noise makes new airport sites in urban areas difficult or impossible to find. In addition, community reaction to noise and the use of land as a noise buffer is causing airports to be located further and further from urban centers. Many existing close-in airports are threatened. The consequences of these conditions is

increasing cost in dollars and time for the home to airport trip. Air transportation, thus, becomes more expensive, but will remain the most viable alternative for long trips. As trip lengths decrease, higher costs and travel times for air travel will make alternative modes more attractive. The pattern of airport locations 'away' from urban areas will, therefore impede the development of short-haul, air transportation.

**Supersonic Aviation Growth is Impeded.** It is axiomatic that unless noise problems (including sonic boom phenomena) associated with supersonic aircraft are resolved, the viability of a supersonic aircraft in the market is questionable. Our international trade/commerce relationships would be at stake as well as the use of the aircraft in the domestic system as it is intended to be used, and, in fact, without such use, there might be little justification for continuing with our SST program.

**Flight Safety is Compromised.** One method for reducing noise complaints is to use noise abatement flight procedures. These procedures are used at low altitudes in the vicinity of airports and consist of using flap and power settings, as well as maneuvers associated with particular flight profiles, to reduce noise impact on selected urban areas. While these noise abatement procedures are designed within the aircraft's capabilities, they restrict the pilot's freedom of choice and often do not represent an optimum flight profile.
Loss of Good Will and Public Support. Operating in a climate of protest has become familiar to airport authorities and officials in large metropolitan areas. This climate has taken years to evolve. PONYA was early to recognize the potential of aviation to disrupt community life. The New York Times in September 1958 reported the feeling of many observers that PONYA in its confrontation with jet engine and airframe manufacturers over aircraft noise had been engaged from the start in a shrewd maneuver. The agency had a double aim. The thesis was, first compel the industry to make a frontal, unstinting attack on the noise problem, and second to squash catch-as-catch-can opposition to jet operations by making itself the chief spokesman for the public interest in keeping jet noise to tolerable limits. It was widely recognized that The Port of New York Authority's position had had a lot to do with the magnitude of the efforts put into noise suppression. In retrospect, it seemed likely to the Times reporter that if the Authority had not laid down a firm policy, community efforts to block the advent of the jet age in New York might have become more effective.

Certainly, the Authority must have recognized that New York would have to adjust somehow to the advent of jets. The chance that other East Coast cities might draw away airline business and with it great sums of money and economic potential could not be ignored. The Port of New York Authority had committed

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a $60 million investment in Idlewild Airport, besides the millions invested by the airlines in their terminal buildings.

In early October of the same year, PONYA moved to permit jet aircraft operations at Idlewild, but imposed at the same time strict rules on minimum altitude, runways to be used, and hours of operation. With jet operations, began a storm of protest unparalleled by any past experience and destined to continue increasing each year with no indication of an end. For those protesting noise, a legal decision of considerable significance was handed down by the U.S. Supreme Court in March, 1962. The Court ruled, 7-2, that airport operators must compensate owners of nearby property for noise, vibration, and fear caused by low flying aircraft. The Court ruled in favor of T.N. Griggs who had lived near the Greater Philadelphia Airport. He had moved out of his home because planes had kept him awake at night and their vibration had caused plaster to fall.

The Court was unanimous in deciding that low flights can make property so useless as to constitute a "taking" of the property for public use. The justices divided on the question of who should pay the compensation. The majority placed the responsibility on the locality or authority that operated the airport. The dissenters thought the Federal Government should pay.

Airport officials weighed the Griggs decision carefully. Basically, they sought an answer to how broadly the case would apply in other litigation. The tendency was to look on Mr. Grigg's circumstances as rather unusual. He lived only 3,250 feet from the end of the runway whose approach path passed directly over his home. The March 11th New York Times reported the following were some of the questions being asked by airport operators and executives:23

1. Would the court look differently at a homeowner who, unlike Mr. Griggs, established residence near an airport after the airfield came into existence?

2. What of the property owner not located directly below an approach path or perhaps further removed from the end of a runway than 3,000 feet, to perhaps a mile or two away?

3. To what extent will property owners be required to demonstrate homes unlivable to win a judgment?

4. How will the court treat cases of lesser hardships?

Partial answers to some of these questions were provided by a 1964 decision, Martin et. al. v. Port of Seattle:24

"Under the Constitution of the State of Washington, which provides for compensation to the owners of property "taken" or "damaged", the court held, among other matters, that properties affected by the noise of landing and takeoff operations need not be precisely under the path of flight to be eligible for relief; further, where the owners of property sue for compensation for rights that have been taken by the result of public action (termed an action for "inverse condemnation"), the court held that compensation must be based solely on the decline in market value of the property."

Most observers agreed that residents who complain about excessive jet aircraft noise seek to end the noise rather than win compensation. For this reason, municipal action such as that undertaken by the Village of Cedarhurst on Long Island has been attempted. Cedarhurst is situated less than one mile from Kennedy Airport. A local ordinance was passed banning airplane flights over the town at altitudes of less than 1,000 feet.

A Federal Judge ruled the ordinance unconstitutional, holding that the airspace was in the public domain and as such was subjected to federal and not local legislation. The consequences of this ruling were far reaching as other communities near Kennedy Airport had planned to enact similar ordinances, if Cedarhurst had been successful.

The limitations placed by the courts on the liability of airport operators and officials for aircraft noise have increasingly turned the more serious citizen effort to limit noise away from the courts to the pursuit of legislative action. In 1970, residents of Boston, as indicated above, worked for passage of a state law prohibiting all landings and takeoffs at Logan Airport between the hours of 11:00 pm and 7:00 am daily. Support for the nightly eight-hour shutdown of Logan was sought through circulation of petitions in some areas near the airport. At the same time, legislation was introduced to prevent the Massachusetts Port Authority from further expanding the airport outward on its land side.

Faced with a future as defender, airport authorities and officials are asking serious questions. The chapters ahead look at some potential answers.

The comments made here are, of course, based on general assumptions, but do demonstrate that there is significant reason for concern on a critical basis. It is also noted that other issues have not been quantitatively stated here, such as the cost of a new airport required by restraint of existing facilities to alleviate noise; the cost of establishing alternate travel modes if noise does, in fact, curtail at least in some areas short-haul air travel; the economic impact on an area due to the loss of adequate air service.
Noise From Aircraft: A Summary

Engine Development. Noise is a by-product of aircraft propulsion, and there is no way to completely eliminate it without also eliminating the thrust required to drive the airplane itself. With each new generation of aircraft, the noise of the gas turbine engine has been reduced, but the change has been slow and the reductions small.

The noise of the initial transports with turbojet engines was characterized by the roar of the jet exhaust. Jet suppressors were developed and installed. These provided only small noise reductions.

The introduction of low-bypass ratio turbofan engines reduced exhaust noise but added characteristic fan tones which are particularly noticeable on landing approaches. Recently developed technology for acoustically treating fan ducts has made it possible to suppress much of the objectionable fan tone with the result that jet exhaust is again the dominant noise characteristic at high engine powers. The cost of acoustical modification of nacelles for currently operational aircraft has been estimated at $172 million to $796 million. Although an increase in passenger fare of less than 1.0 percent would completely offset the cost of a retrofit program, the air carriers would be faced with a major cash outlay for retrofit over the projected three-year implementation period. There has been strong carrier opposition to retrofit.
Research programs have provided the fan design and acoustic treatment technology for reducing fan noise in high-bypass ratio turbofan engines. Also, the high-bypass ratio engine has low jet exhaust noise with these engines. A high-bypass ratio engine could be developed to re-equip the existing civilian jet fleet. The total cost of this program has been estimated to be approximately $2 billion. The time required to complete an engine replacement program, should it occur, would be over five years. Again, there has been intense carrier opposition.

The vast majority of aircraft in commercial service today are powered by low-bypass ratio turbofan engines. The bulk of this fleet will remain in service over the next fifteen years.

Responsibility for Flight Noise Being a Problem. Before the jets, airports created little more than a minor nuisance. Most airports were located near the edge of the city. Relatively quiet piston-engine airplanes were in service, and operations were few in number. Later, just as jet-powered aircraft were being introduced, urban centers were expanding outward to engulf airports in remote areas. Today, development presses close to airport boundaries exposing people to aircraft noise, and consuming sites that might otherwise have been suitable for an alternate or additional air facility. Moreover, the need for airline service has increased
most in the very regions where there are severe limitations on further expansion of existing facilities. Sites appropriate for new jetports can only be found prohibitive distances from the urban centers to be served.

The will to regulate noise-sensitive development did not exist either in the air transport industry or local government units. Individually and collectively, every sector of the air transport industry tended to regard what went on outside the airport fence as outside their jurisdiction. The air transportation industry and the governmental agencies established to regulate and promote air commerce understandably placed very low priority on the sensitivities of the non-flying public. Their main concerns were with air safety and overcoming public fear of flying. The shortsightedness and vulnerability of local government units which could have regulated noise-sensitive development by zoning or other land use controls has been documented.

The intent here, however, is not to suggest that environmental conflicts between airports and their surroundings derive primarily from encroaching urban development or, further, that undesirable impacts are limited to the urban environment. Many noise impacted land uses and activities existed long before airport operation, or expansion became offensive. In short, the major advances in aviation technology are what have created
today's flight noise problem. Increased passenger demand, unwise development decisions, and the inability of the planning process to prevent encroachment around airports of various types of incompatible uses have exacerbated the conflict between airports and their neighbors. But the most significant factor has been the change from piston to jet-powered aircraft and the consequent change in facility requirements.

A New Awareness. Since the transition from piston-powered airplanes to jets, and the accompanying significant alteration in the character and level of airplane noise, the conflicts between airports and their neighbors have steadily increased. In the recent past, every attempt to expand existing major airports or build new ones has met with intense resistance -- from citizens, local governments and conservationists.

In Boston and New York, the opposition encountered in the recent attempts to expand airport facilities, as observed in Chapter II, was sufficient to totally stop expansion in both cities.

Also, during the recent past, the attention of the public and government has been directed towards all environmental problems to an unprecedented degree. Aircraft, among the most visible sources of both noise and smoke, have been major targets of environmentalists, and media, and political leaders. To what
extent will flight noise be reduced as a consequence of the elevation of environmental concern? And, to what extent has the elevation of environmental concern caused the level of opposition to aircraft noise to change independent of changes in the level of the problem?

The answer to the first question is tied closely to changes in the policy arena. Until recently, most natural resources decisions have been made in what political scientists classify as a "distributive" policy arena.\(^{26}\) In the distributive arena, the only question is how much pie you can get and when. There are no winners and losers, only differing degrees of winners. The aviation community has long functioned in a distributive policy arena. As a result, the industry has never come to grips with its role in society at large. It operates on the simple assumption that whatever is good for aviation is good for society as a whole. The extent to which the air transportation industry recognizes and responds to the damages caused by flight noise in large part will be a function of the environmental movement's success in mandating that future decisions be made in a "regulatory" policy arena. In this arena, rather than agreements of mutual non-interference, coalitions form around a shared interest. Competition is more intense in this arena because both sides cannot be accommodated.

The defeat of the Florida Everglades Jetport is the result of a formerly distributive arena turned highly competitive.

The resolution of conflicts in a regulatory policy arena depends in turn upon which participant is allowed to define the "public interest." "Thus far," says Professor Joseph Sax in Defending the Environment, "both the legislature and courts have fixated on the administrative process as the mechanism for identifying and enforcing the public interest."27

In general, according to Sax, this mechanism has allowed powerful economic interests to control the defining of the community; thus, they controlled the definition of the public interest. "The public has remained on outsides, to be tolerated as a recipient of notices and participant at formal hearings, but not as a central player."28 Noise alleviation is affected by this situation. The industry is a powerful economic interest which argues that it is in the public interest for a community to establish and maintain air transportation services. To impose the cost of noise alleviation on the industry would be unfair because it would hamper growth of the industry or even destroy it; thus, preventing the industry from benefiting the community. In fact, the only community in whose direct


28 Ibid.
public interest a comprehensive noise alleviation program would be contrary is the community centered around the major air carriers and their employees. It is this extremely narrow definition of the public interest that is being called into question.

This brings us to the second question. To what extent has this new awareness resulted in changes in the level of opposition to flight noise which do not reflect a change in the level of exposure. The answer has two parts. First, the obviously noisy presence of aircraft has helped focus the concern of many local groups which organized after the single issue was settled, and sought for more environmental issues to become involved in. Second, the frequently made proposal to expand the capacity of metropolitan area airport systems by building a new air carrier airport has generated broad community concern with and opposition to airport development in general and flight noise in particular. Faced with the choice, apparently no one is personally willing to sacrifice the things he values -- whether these be peace and quiet, safety, or a few remaining acres of open space -- for the "benefits" bestowed on the community by the air transportation industry.

The Problem and Public Policy. It is evident that flight noise is seen by the public, policymakers, and administrators as a problem to be solved.

A problem is said to exist "when our view of what conditions are, does not square with our own view of what
they should be." In other words, problems are a function of values or goals. No conceptual difficulties exist in moving from perception of the flight noise problem to identification of the public policy goals that should be served in plans and programs involving the flight transportation industry. Rather, difficulties exist in identifying how the particular shape of the flight noise problem justifies public policy action.

One view of flight noise sees it as a problem with measurable consequences in which regulation standards respond to measures of damage, measures of incidence, or some other arbitrary or precise understanding of its significance.

This inquiry reviews one of the two essentially similar cases involving flights over neighboring properties in which the Supreme Court has awarded damages, Causby v. United States and Griggs v. County of Allegheny. 30,31


30 328 U.S. 256 (1946).

31 396 U.S. 84 (1962).
In each of these cases, there existed both the invasion and exclusive use which are required under the federal constitution to effect a displacement of the property-owner and justify compensation. Following the Griggs decision, airport officials questioned how broadly the case would apply in other litigation. The "taking" was not based on the existence of an objectionable noise. In this and the Causby case, aircraft passed over the plaintiff's land at low altitude. This effectively displaced the plaintiff. If the plaintiffs in Causby and Griggs had merely been subjected to the noise they experienced, no recovery would have been allowed.

The findings of the Washington State Supreme Court in Martin v. Port of Seattle broadened the precedent established in Causby and Griggs.32 Recoveries in the Martin case were based on the theory of unconstitutional taking or unconstitutional damaging without compensation (inverse condemnation). The test for inverse condemnation is whether low and frequent flights have substantially interfered with the current use of the plaintiff's property. Damage to property was proved by reference to comparative real estate values and compensation based on the amount of decline.

32 391 P 2d 540 (1964).
The reason that the courts have restricted the right of recovery to those plaintiffs whose current use of their properties is substantially interfered with by low and frequent flights is that some sort of line must be drawn by the court, which has only particular plaintiffs and particular issues before it, between compensable and noncompensable damage.

The legal problem involved is a difficult one: where is the line to be drawn? Lawyers consider the common-law concept of physical invasion embodied in the constitution to be the easiest to apply of all possible choices, assuming that compensation is to be granted at all. The extended controversy over this relatively simple standard following the Griggs case illustrates what is likely to happen if a more complicated standard like that suggested by Martin were adopted. It is clear that the line has to be drawn somewhere. In legal proceedings, a question is either lawful or unlawful.

These circumstances have led one lawyer to conclude that:

"Relief for such widely shared annoyances is more appropriate for consideration by legislative bodies or administrative agencies which can deal with wider interests and issues than those of particular plaintiffs before the court. Across-the-board compensation to all residents in an arbitrarily determined zone bears little or no reference to actual damage or interference and takes the court into a realm where legislative or administrative techniques ought to apply."

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33 Lyman M. Tondel, "Federal Regulation of Aircraft Noise, the Legal Aspect of Compatible Land Use," Society of Automotive Engineers Paper 710335 (February 1971).
In light of this evidence, it is appropriate to adopt the alternative view that flight noise is a general "malaise," known to be damaging, recognized as impossible to eliminate entirely, but impossible to measure qualitatively in terms of its effects, such that it ought to be subjected to administrative and legislative efforts toward minimization. A program to alleviate noise can be derived from the results of investigation in the next chapters. The extent of the effort applied to solving the noise problem would be determined by the political process.
PART 2
CHAPTER V

METHODOLOGY FOR EVALUATING NOISE REDUCTION TECHNIQUES

The objective of this chapter is to describe a methodology for evaluating noise reduction techniques.

Elements of the Methodology

Solutions are to be evaluated by an analytic scheme involving these variables: Effectiveness, Scope, Cost of Implementation and Limitations.

Effectiveness. Before officials proceed on any one noise-reducing technique, the cost involved in initiating and continuing a proposed program versus the environmental gains to be made must be estimated. This is termed the cost-benefit analysis, subtracting the costs of control from the probable benefits.

As simple as the approach sounds, it meets many snags when implemented. First, damage due to pollution is difficult to measure. Actual physical damage eludes researchers because of the complexity and variability of quantity of pollutant and degree of damage. Impairment to human effectiveness, well being, or loss of aesthetic values are all non-physical damages more difficult to quantify than the physical. The result is that the latter are too frequently ignored. To leave these non-physical issues entirely out of all calculations determining the costs to the environment understates the
the entire problem.

All interpreted gains are thereby also understated and necessarily bias damage measurements. Other biasing factors, as Ridker substantiated, are built into the methodology used to measure economic consequences.\(^1\) Such biases consistently understate to costs of pollution. Such biases are those of the researchers failing their objectivity:\(^2\)

"Those that will have to pay for environmental improvements, such as businesses and municipalities, tend to inflate costs and deflate benefits. Those who particularly want the improvements can be counted on to do the reverse."

All the problems of measurement and objectivity frustrate the efforts of lawmakers. Currently, the Federal Government is in the process of establishing standards for environmental quality. With regard to aircraft noise, Public Law 90-411 is an example. Beset by these difficulties, these standards are potentially arbitrary and suboptimal; that is, they may over-control or under-control pollution. Advocates defensively argue that elected representatives are attuned to attitudes that form psychic costs, and since these are a large portion of the total costs, their assessments are near the mark. Until these standards can be improved upon, they must be followed as the only uniform guidelines available. Every effort

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2 Sanford Rose, "The Economics of Environmental Quality," Fortune, Vol. LXXXI, No. 2 (February 1970), p. 120.
should be made to achieve these ends in the most expedient and least costly way.

**Scope.** Methods of curbing noise fall into three broad categories:

1. Reduction at the source
2. Insulating people
3. Isolating people

All three are considered in the next chapter. Each method is studied to determine if it benefits a single airport or the entire airport system.

**Cost of Implementation.** Implementation is considered in the evaluation from the standpoint of cost. What will the alternative cost and upon whom will the cost fall? The method described in "Effectiveness" will be used to answer the first part of this question.

The second part of the question demands that the equity of these costs be considered. Airports now dispose of their unwanted by-products, such as noise and air pollution, on neighboring land. These externalities frequently limit the use of that property, thereby eliminating alternative uses of the resource to the owner (and society). By preventing certain uses, the airport consumes the resource.
Chapter VIII discusses issues of pollution economics and poses a possible answer to the question of upon whom the cost of making quiet should fall.

**Limitations.** Factors which limit the development, application, or operation of noise reduction alternatives will be discussed. For example, while it is technically possible to build near airports with satisfactory interior noise levels, this is practically only for activities carried on entirely indoors. Commercial office structures, industrial buildings, and hotels may, thus, be feasible to locate near airports, but single-family residential development is highly questionable. Outdoor area free from high noise is needed for children's play and other outdoor family activities. This factor limits the alternatives and is illustrative of one type of limitation identified.

Another type of limitation studied is the technical possibility of a solution's implementation. Evidence is sought from reliable sources to determine the technical possibilities of the various alternatives to relieve the noise problem.

**Noise Reduction Alternatives**

The alternative solutions to the aircraft noise problem evaluated in Chapters VI and VII are:
1. Land use management.
2. Land acquisition and avigation easements.
3. New facilities.
4. Reduction of aircraft noise at the source.
5. Operational changes.
6. Diversion to other modes.
CHAPTER VI

AN EVALUATION OF METHODS
TO CURB EXPOSURE TO AIRCRAFT NOISE

Introduction

Airport noise is the single greatest factor aggravating community-airport relations. Communities mobilized against prolonged noise exposure or its threatened possibility, possess significant strength to inhibit aviation growth.

This chapter considers ways of achieving compatibility between the growing flight transportation industry and surrounding urban developments. Preventative and remedial actions designed to lessen noise are reviewed and compared.

Land Use Management

Frequently, authorities suggest control of land use as a means of solving the noise problem. There are many techniques for regulating land development, or for converting and modifying existing land uses to achieve greater compatibility between the airport and its environs. Easily the best known of these methods is zoning.

Zoning. Zoning is a system of legal restraints on the use of land and the structures placed on the land. It can
determine the character and shape of the urban environment. Where zoning has been based on a well thought out, long-range, comprehensive urban plan and has been intelligently administered, it has been a powerful instrument, successful in preserving the quality of a community.

Usually, its application has been only partially successful, however. Good results have been more common in small communities rather than in large municipalities or cities.

Lack of effective zoning around many airports has permitted residential encroachment. Dulles Airport is a case in point. Some of the weaknesses of zoning are inherent; others are the result of poor administration. A primary weakness is that in most instances, zoning cannot be retroactive. Structures or uses that antedate a zoning ordinance which are at odds with the long-range comprehensive plan backing up the ordinance are typically exempted from ordinance requirements. Other weaknesses of zoning are: the essentially negative character of the instrument and its relative lack of flexibility in the face of swift changes in technology and living patterns; the general insistence that it be effected exclusively at the local level; and the lack of understanding on the part of many officials of the proper role of zoning.
. Negative Character of Zoning. Zoning developed from simple controls over land that were based on nuisance. Ordinances continue to exist which consist of long lists of prohibited uses. With the passage of time, the kinds of uses that may be compatible or incompatible in an area change, weakening the ordinance. Further, such zoning becomes a restriction on private development.

. Lack of Flexibility. The basis for zoning derives from the police power of the State government which allows the regulation or restriction of private action in the broader interest of the health, safety, morals, or general welfare of the community as a whole. The precise powers required by local officials to effect certain zoning techniques have been lacking due to the omission or by the lack of clarity of the language in the state enabling legislation. Zoning innovations invariably face a test in court. A community undertaking zoning innovations must, therefore, be prepared to face long and expensive court proceedings. Recently, the U.S. Supreme Court dealt a setback to airport zoning in the case, Indiana Toll Commission v. Jankovich.¹ The Court upheld a state decision which concluded that the airport zoning ordinance in Gary was unconstitutional. The ordinance was based generally on a

¹ Indiana Toll Road Commission v. Jankovich, 193 NE 2d 237, (1963)
model state airport zoning act which has been advocated by the FAA for several years and which has been widely adopted.

Extra-territorial Jurisdiction and Administrative Problems. The extent to which a community is affected by aircraft noise varies from airport to airport. Effect is conditional upon such factors as runway orientation, size of airport, type of aircraft using the airport, frequency of operations, proximity to other airports, etc. What is generally misunderstood is the scale of the noise-affected area. It is not uncommon for communities as many as ten miles from the airport to experience some effects. Land use control around a major airport is made difficult by this scale problem. Frequently, the area is administered by several governments. Further, government-held authority and responsibility for aviation activity is widely distributed and fragmented. On the local level, authorities who operate such public-service facilities as transit systems, seaports, and airports are frequently found separated from the central municipal organization. Almost exclusively the federal government has concentrated on the air side of aviation. Stated federal government responsibility, prior to the recent passage of the Airport and Airways Development Act, ended at the point the runway met the ramp.
Recognizing the multiplicity of jurisdictions involved in aircraft noise problems generated by a single airport is the key to understanding the complexity inherent in an attempt to foster community-airport compatibility. For the airport owners and operators who do not have the legal authority to enact or enforce land use controls, the main problem is one of convincing appropriate local or state political representatives to enact such controls.

Those governmental units owning and operating airports which have the power, or obtain such powers through local officials, have no authority beyond their jurisdictional boundaries. The residents of airport surrounding areas, who are adversely affected by aircraft noise, are instituting many suits against airports. To be successful, they must convince local officials to act on their needs. The feasibility of their campaign can be evaluated after reviewing the process of local decision-making and the record of politicians.

Decisions regarding land development involving land use controls typically are made on the basis of narrow considerations, often ignoring important area-wide or metropolitan goals. The most common considerations are the returns the investor wants to obtain on his property, the local government's interest to increase the tax base, and the interests of the residents to maintain or improve the value of their homes.
Carefulness and conservatism characterized most public decisions. Commonly, only those decisions which do not create turmoil, avoid risk-taking, or do not greatly alter the community's physical form are made by public officials.

For the airport environs, as well as for the total metropolitan pattern, the cumulative total of such local decisions has seriously undermined comprehensive planning seeking balanced regional development and betterment. Such results confront airport authorities and officials with a legacy of development incompatible with their operation.

**Building Codes and Acoustic Treatment.** Building codes, which effect building construction, are a means of enforcing acoustic standards. They constitute the primary device available to local officials to insure that minimum standards for light, ventilation, safety, sanitation, and fire protection are met. Building codes can logically be extended to include soundproofing provisions in noise-affected areas.

Building noise reduction calculations performed by Arde, Inc. indicated that the average woodframe structure will reduce noise 30 decibels with closed windows.²

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As long as the exterior noise level is not more than 30 dB above that desired indoors, interior noise will be acceptable. An acceptable interior noise level is 60 PNdB. Turbojet and turbofan aircraft noise exceeds 110 PNdB two miles from the runway threshold. (See Figure VI-1).

Arde, Inc. cost estimates indicated that soundproofing could be installed in existing structures at a cost of about one percent of the building cost per decibel of extra noise reduction up to about ten dB. A total noise reduction of 40 dB (30 + 10) is, thus, possible. Storm windows improve noise reduction by about 2 dB at a cost of about 2 percent of the base cost of the structure (See Table VI-1). Obtaining more than 10 dB noise reduction requires basic changes in the structure rather than simple add-ons.

To soundproof a one or two-story structure during construction adds about one percent to the cost per decibel of extra noise reduction. In a building initially designed to be soundproof, total noise reduction is not limited to 10 dB.

An average multi-story, commercial building reports Arde, Inc., has a noise reduction of 35 dB. Additional noise reduction costs 1-1.5 percent of base cost per dB.

Since windows must be kept closed for noise reduction, extractor fans or air conditioning are required. Air
conditioning costs are about 10 percent of the building base cost; extractor fans about one percent.

Using the population estimates given in Table VI-2, sample costs for acoustic conditioning of residential structures can be estimated (See Table VI-3). In these calculations, the total number of persons exposed to high levels of aircraft noise levels is divided by a constant representing the average number of persons per family. Each family is assumed to occupy one dwelling unit.

At an assumed value of $10,000 per dwelling unit, acoustic conditioning of noise affected residential structures in 1975 in Los Angeles, Chicago, and New York would total $68,660,000. Non-residential structures needing sound reduction modifications would add to this cost. At present, the FAA recognizes 22 cities as large hubs, and additionally there are numerous medium and small hubs. The three cities specifically mentioned are but a small part of those areas affected by jet noise.

Acoustic treatment is subject to a serious limitation. It is not effective for uses which involve outdoor activities. Residential occupants are likely to be outdoors in good weather. Once outside, they will receive the full impact of the aircraft noise. Further, only new construction comes
under the auspices of building codes; hence, like zoning, they leave unaffected structures antedating the provision.

Another problem with housing codes, for which they are notorious, is their lack of commonality and standardization. Being local in origin, every major metropolitan area has scores of different codes with widely varying construction standards. Standardization and simplification of building codes is necessary before their potency as an effective planning tool can be fully realized.

A frequently asked question is whether property owners who acoustically treat their structures should be compensated by air carrier passengers? To date, the actual award of compensation has depended on the courts' interpretation of legal liability.

Since 1955, about $1.5 million has been recovered in known airport cases. With few exceptions, recovery was based on the ground that the governmental body involved (the airport operator) had either "taken" an avigation easement over private property without compensation or had "damaged" the property to an extent constitutionally prohibited. In the Griggs decision, the test for taking -- whether the over-flights make the property unusable for the purpose for which it is being used -- was applied and upheld.
A constitutional damaging case, *Martin v. Port of Seattle*, was decided by the Supreme Court of Washington.\(^3\) The Port was found liable for any damage caused by aircraft operations. Damage was held to mean any proven decline in the market value of real estate that resulted from the operation of jet aircraft in and out of the airport. *Martin* is the only known case in which damages have actually been recovered without any requirement of a showing that the damages claimed are at least "substantial".

How much "damage" does an airport cause? According to a PONYA report, airports do not adversely affect the market value of surrounding property.\(^4\) In fact, in some cases, proximity to the airport was the apparent reason for higher prices than would otherwise be justified.

Thus, in a legal context, to be compensated for costs incurred as a result of acoustically conditioning a structure, given the Court's criteria for computing damages (decrease in property value), new legal ground will apparently have to be broken.

**Taxation.** A final traditional land use control device is taxation. Cities are empowered by state legislation to

\(^3\) *Martin v. Port of Seattle*, 391 P 2d 540 (1964).

levy taxes to provide revenues for municipal services. Local taxation powers are extended in an explicit manner. The form of tax which may be used is prescribed, and the maximum rate, particularly of property taxes, is restricted. The principal constitutional requirement of due process of law as applied to taxation is that the tax be uniformly applied. The uniformity requirement does not prevent cities from establishing categories for tax purposes, nor from assessing different classes at different rates, but it does not allow "arbitrary" classification and unequal assessment.

A special kind of taxation authorized by the constitution of several states explicitly authorizes diversity in classification. Special assessments and exemptions are made possible under this provision. Exemptions from the property tax have long been a favorite way of encouraging desired land use development. Giving preferential tax treatment to non-noise sensitive activities could attract them to the vicinity of airports. The exemption of the cost of soundproofing from property tax assessment could encourage soundproofing of existing structures and soundproof construction of new ones.

Exemptions means a loss of revenue. Whether the amount would be excessive causing a shortage of needed facilities and services cannot be answered by theory. As a
practical matter, the question can be answered only after exhaustive tabulation of empiric data.

Working properly, land use management should be able to produce a compatible relationship between the airport and the community. In actual practice, it has fallen short of its desired objective. In operation, this solution asks persons and businesses adversely affected by aircraft noise to curb their own exposure to it. The associated administrative limitations and subjectivity of land use controls to political manipulation limit their effectiveness. Finally, noise is in no way reduced by land use management, only exposure to it.

Land Acquisition and Avigation Easements

Usually acquisition would involve buying entire large communities. If PONYA were to try buying out its noise problem, large portions of Brooklyn would have to be purchased to cover one direction. Even if large scale buy-outs could be afforded by local communities or airport authorities, any attempt to force large segments of established communities to sell their properties and move away would precipitate a monumental citizen protest. Even the Massachusetts Port Authority policy of purchasing properties only as they are put on the market in
the natural course of events has produced bitter protest from community residents, as observed earlier. MPA established the program only because certain geographic features combined to make it practical. Logan Airport is situated on a peninsula. Relatively large bodies of water separate at least one end of nearly every runway from surrounding development. With the exception of operations in the direction of South Boston, the settlements close to the threshold of active runways are small enough in terms of affected population and property to be within the MPA's long-range buying power.

On balance, the potential usefulness of land acquisition at established airports is negligible. For new airport construction, a policy of early acquisition of land in the airport environs or at least purchase of development rights would clearly have many benefits. Under the ownership of those charged with responsibility for the airport, only development compatible with high noise levels could be allowed. Conflicting demands for property development could be better dealt with by authorities with more specific goals than those of the municipal government.

The feasibility of advance acquisition is dependent in turn on the feasibility of new airport construction. This issue is discussed in a forthcoming section.
Limited fiscal resources, enormous costs, and strong local opposition make outright acquisition of property and unsatisfactory policy. Another less-expensive version of this same policy has also been suggested. It is airport authority purchase of avigation easements -- the right to use and create noise in the airspace above private property. Whether this approach will be particularly useful or successful is not yet determined.

Commenting on this approach, ICAO has said: ⁵

"Since avigation easements sometimes run as high as 75 percent of the total cost of the property -- they are expensive. Also, many airport owners and operators have the legal authority to acquire avigation easement by purchase only if directed to do so by court order."

"Further, avigation easements have been held by a number of courts to relate only to the types and quantities of aircraft operating at the time the easement was granted; and new easements must be purchased if the character of the noise changes -- such as with the introduction of noisier aircraft."

"But, most important, the people on the ground are still subjected to the aircraft noise. To them, court enforced purchase of the right to use the airspace above their homes does not lessen, in any way, the amount of noise they are subjected to on the ground -- with resulting and continued social and political problems."

A variation of the avigation easement is argued for by Altree: requiring the airport to buy their easements in smaller pieces.6

"The extent of an easement can be measured by at least two dimensions: the permitted noise level and the length of time over which that noise level may be imposed. The present case law on airport noise has recognized the significance of one of these dimensions: that of noise level. In airport noise litigation, the ultimate question presently asked is, 'By what amount has the market value of the affected property been depressed by the imposition of presently prevailing noise levels?' When that question is answered, the airport gets an easement to continue forever to impose that noise level, and it is required to pay the decrease in market value. If significantly higher noise levels are imposed at a later time, present case law allows the affected properties to bring second inverse condemnation action."

Altree urges that the time dimension of airport noise complaints be given similar recognition.7

"The ultimate question to be asked when the first easement was to be paid for would become, 'By what amount has the fair rental value of the affected property over the first ten years of airport operation been decreased by the imposition of the noise levels that have prevailed during those years?' When that question is answered, the airport would be required to pay the loss in rental value and would receive an easement to impose the noise levels during that time period; it would not receive any immunity from liability for imposing any noise beyond the end of that time period. At a later point in time, the same question would be asked of the next ten year block of time."

7 Ibid., p. 73.
Altree does not offer her proposal as a solution to the aircraft noise problem. Rather, its purpose is to resolve the most obvious and equitably intolerable instances of income redistribution and realize a rough approximation of economic efficiency. One of the strengths of the time-limited easement is that it maintains incentive on the part of engine and airframe manufacturers and carriers to curb aircraft noise. Until the noise is curbed, these parties will pay for the disturbance. With this purpose in mind, their proposal has merit.

New Facilities

A new airport and the acquisition of sufficient surrounding property to serve as an effective noise buffer zone is a potential means of curtailing community noise exposure. Evidence assembled in Chapter II indicated that no new airports are likely to be built in the United States in the foreseeable future, however. Others echo this conclusion.

Professor Robert Simpson, speaking before the Air Transportation Meeting of the Society of Automotive Engineers said:8

"We have reached the point where increased or new jet airplane operations will not be tolerated by surrounding communities in any area which provides acceptable access to the traveling public. The fourth airport problem in New York has gradually become a spectre as comprehension of

of similar problems in locating new airports has occurred in other cities."

The inability to build new airports relatively close to cities has logically lead to contemplation of construction in more remote areas. Here, too, considerable resistance has been encountered. The "growing U.S. anti-pollution drive could mean the end of new large airport construction designed to relieve congested air traffic areas," reports the Aviation Week and Space Technology, "Airline Observer."9 "Outcries by conservationists and ecologists against stripping massive sections of land for airports would discourage the underwriting of state or municipal bonds for financing."

The conclusion is the existence of a low probability of any new large airports being built.

Reduction of Aircraft Noise at the Source

Each of the methods so far have been "on the ground" solutions. "In the Air" solutions are a second category. The first of these is a frontal attack on the noise source: putting pressure on the engine and airframe manufacturers to modify aircraft engines to reduce the amount of noise and to change the characteristics of the sound generated. PONYA realized some success with this strategy at the advent of air passenger transportation by jet. More recently, both Massachusetts

Port Authority, through the Logan Airport Noise Abatement Committee and the Aviation Department of PONYA have strongly supported the campaign for certification of aircraft for minimum noise levels. Testimony before a Congressional Committee and numerous contacts made with the Congressional Delegation preceded the passage of Public Law 90-411.

Aircraft noise certification provides a means for dealing with future aircraft but leaves unresolved what to do about the existing civil jet fleet. Proposals have been put forward to re-equip and retrofit the present jet fleet with quieter engines. Strong opposition to these plans from the carriers has developed. Their objections center mainly on the cost burden involved. The issues and costs can be identified and quantified.

Re-equipping the Existing Jet Fleet. Basically there are two sources of noise from jet engines. One is the compressor blades working in the air; the other, the jet exhaust. Jet exhaust is caused by turbulent mixing of the high-velocity exhaust gases with the ambient atmosphere. The noise source is not located at the nozzle exit, but rather downstream in the mixing region, 5 to 50 feet behind the nozzle. Jet exhaust noise is quite directional with maximum directivity occurring
at an angle of about 45 degrees to the direction of the exhaust.

Jet noise is a function of jet velocity. The only significant way to reduce jet exhaust noise levels is to reduce the jet velocity. Suppressor nozzles have been designed to cause more noise-preventative mixing. Current jet nozzles, daisy-shaped or multi-tubed schemes, suppress noise by 3 to 4 PNdB but incur a penalty in loss of thrust, one percent or more, and increase engine weight and cost.

By increasing the by-pass ratio, the jet velocity can be lowered. Some of the energy which would have gone into the main exhaust is used to turn the by-pass fan. An increased volume flow and much lower exhaust velocity results. Also, the low-velocity fan exhaust decreases the shearing forces and provides a layer of cool turbulent air around the jet acting as a muffler.

Current fan-jet engines produce 5 to 8 PNdB less noise than an equivalent turbojet. Advancements in several areas of airplane engine technology have opened the possibility of developing turbofan engines with much higher bypass ratios than those used on the JT3D and JT8D.\textsuperscript{10} These engines

\textsuperscript{10} The JT3D is a turbofan engine which was derived from the JT3C turbojet engine and is used to power later versions of the 707 and DC-8, which
provided significantly lower fuel consumption. Also, the engine concept was sufficiently different that many new design features to minimize noise could be exploited. It appears that the concept of high-bypass-ratio engines offers greater possibilities for noise improvements than offered by any past design concept.

The engine size selected to power the wide-bodied 747, DC-10, and L-1011 jets is in the 40,000-pound thrust class, or about four times as large as the early turbojet engines, while the engine airflow to provide this thrust is nearly ten times greater. The jet velocities, however, are low which results in low levels of jet noise in accordance with the principle previously discussed of moving large quantities of air at low velocities to create thrust. The trend of jet noise versus bypass ratio for a given thrust size engine is illustrated on Figure VI-2. Based on this trend, and other engine design considerations, a bypass ratio of about 5 was selected for the JT9D Pratt & Whitney Aircraft engine, which represent the majority of airplanes now in active airline service. This engine is still being produced.

The JT8D is a second low-bypass-ratio turbofan engine similar to the JT3D developed to power the 727 three-engine transport and the 737 and the DC-9.
is typical of a modern high-bypass-ratio engine. Although slightly lower jet noise levels could be achieved with higher bypass ratios, the additional small noise improvement was not justified by the increased complexity in other areas of engine and airframe design. At the bypass ratio selected, the engine has over 20 PNdB less jet noise than a turbojet design of the same thrust.

With the dramatic improvement in jet noise associated with the low-jet velocity of the high-bypass-ratio engine, it became clear that great care must be taken to minimize noise from the fan, particularly the shrill tones at landing power. However, the requirement for low-fan noise is not inconsistent with the overall concept of the high-bypass-ratio engine:\[\text{11}\]

"Blade noise is that generated by the compressor, turbine, and the bypass fan...The major factors that control the wakes of the inlet vanes and downstream fan blades, or the wakes of the fan blades and exit vanes further downstream. Such interaction is a function of both axial spacing between rotating fan and stator vanes, and the relative number of blades that each has."

The wake interaction is the cause of the commonly heard jet-engine compressor whine.

There are two ways to reduce the compressor noise produced by a jet engine. The first is to reduce the noise at the source. This involves making fundamental changes to the engine. The axial space relation of engine rotor to stator has an important effect on generation of compressor noise, the greater the spacing, the less noise produced. Figure VI-3 illustrates the effects of axial vane-rotor spacing. Noise generation is also influenced by the relation between the numbers of rotor blades and vanes. Noise can be reduced somewhat by using a large number of vanes relative to the number of rotor blades. Using a large number of inlet vanes can lead to trouble because of the requirement commercial engines be able to swallow seagulls, duck, and other birds. Engine stall or malfunction could result from birds becoming lodged on the inlet guide vanes. This problem can be circumvented, if the engine design can afford it, by eliminating the vanes. The Pratt and Whitney JT9D in service on the Boeing 747 has no inlet vanes. A quieter and lighter engine also results.

The second way is to reduce the noise output of the engine by the addition of various external devices. This approach, called retrofit, is considered in the next section.

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Engines for the DC-10, L-1011, and Boeing 747 are all high bypass and have no inlet vanes. Commercial operation of the Boeing 747 airplane, powered by Pratt & Whitney Aircraft JT9D high-bypass-ratio engines was initiated in February 1970. Much concern was expressed by uninformed people that the large powerplants of the 747, which produced well over twice as much thrust as any commercial aircraft engine then in operation, would be also twice as noisy. However, not only has the 747 indicated lower decibel readings on noise measurement equipment, it also has been found to be subjectively quieter than other airplanes. The typical noise characteristics of airplanes with high-bypass-ratio engines are described below.\(^\text{13}\)

. Sideline. Lower jet exhaust rumble contributes to the low 103-EPNdB value of sideline noise measured during the takeoff of airplanes with high-bypass-ratio engines at full power. The peak noise level is reduced, but equally significant, the rapid dropoff of noise after the airplane passes by, a marked contrast to the persistent low-pitched rumble of earlier powerplants. These factors combine to produce a very acceptable subjective assessment of high-bypass-ratio engine sideline noise.

Takeoff Noise. Typical fully loaded transports powered by high-bypass-ratio engines will produce noise levels between 104 and 110 EPNdB at the 3.5 nautical mile takeoff point with the use of thrust cutback. As in the case of sideline noise, the rapid dropoff in noise after the airplane has passed overhead contributes to the favorable subjective reaction.

Approach Noise. Although the wide-bodied airplanes are much larger than earlier airplanes, they must still follow the same landing path and pass over the approach noise monitoring microphone at an altitude of only 370 feet. Noise levels under these conditions will range between 108 and 111 EPNdB. Subjectively, the reduced prominence of the fan tones from these airplanes contributes to a less irritating sound quality.

In summary, the combination of fundamental engine design for low noise and the installation of the engine in a nacelle with extensive noise suppression treatment has resulted in a significant improvement for the new-technology airplanes compared to the current airplane fleet. This is especially important when one realizes that these new airplanes represent an improvement for the complete airport environment as opposed to an improvement at only one or two flight points. As an example, the reduction of noise levels observed today at large airports, is numerically indicated on Table VI-4.
This numerical reduction, as well as the subjective improvement accompanying these lower noise levels, positively demonstrates the successful application of noise reduction research and development efforts.

Although the high-bypass-ratio engine represents an improvement in airplane noise, it does little to alleviate the noise from the large fleet of existing airplanes that still have many years of useful life ahead. How to cope with the noise problem of existing airplanes is a topic for continuing and serious study by the government, the airlines and the manufacturers. One question often asked is: "How can the noise technology of high-bypass-ratio engines be adapted to current airplanes such as the 707, DC-8, 727, DC-9, and 737?" Although no simple answer to this question is possible, considerations relevant to this subject will be presented.

Direct replacement of existing turbojet or low-bypass-ratio powerplants by existing engines as the JT9D does not appear possible. The physical size of available high-bypass-ratio engines is such that they would not fit between the airplane wing and the ground, and existing airframes could not withstand the weight and thrust loads imposed by these engines. Therefore, a totally new, smaller engine would be required.
Even though high-bypass-ratio engines of a large size have been designed and are in operation, a considerable period of time would be required to develop a smaller version of these engines for commercial use. With an aggressive program, it may be possible to certify an engine to meet commercial airworthiness standards in about 4 to 5 years from program initiation. Time is also required to develop installations for such an engine for each of the many different versions of the five basic types of aircraft presently in service. Unique installation features are associated with each model of an airplane type; hence, several differing nacelle installations could be required. In some cases, a new wing might be required because of structural load changes.

The buildup of the current fleet occurred over a 12-year period. After a retrofit engine was granted an airworthiness certificate, it would require several years to produce and install engines to replace 12 years of past production. Consequently, even if it could be clearly shown that such a retrofit program would serve the best interest of all concerned, a minimum elapsed time of about 6 years from the start of such a program would be required before the community would begin to realize its benefits.
Nacelle Retrofit. Acoustic treatment techniques seem the best retrofit mechanism for noise abatement. One technique developed by McDonnell Douglas consists of an acoustically treated fan inlet and fan duct. Specifically, their nacelle modifications were designed to be employed for JT3D-3B powered DC-8-55 airplanes. Noise predictions and economic effects apply only to this particular engine-plane configuration. Although differences exist for other JT3D installations or installations of other turbofan engines, the results are representative of costs associated with a given level of noise reduction through the use of acoustic treatment.

The predicted instantaneous perceived noise levels for landing are shown in Figure VI-4. The time scale is relative to an arbitrary zero reference time representative of when the airplane would be approximately directly overhead. The 8-


15 No actual flight tests had been conducted on the new nacelle, only ground tests. Noise levels indicated by the ground testing were extrapolated to actual flight conditions. Many variables enter the extrapolation process, preventing positive predictions from being made. An error range for all estimated values is included.
second time interval shown represents the time period over which the noise would be heard one nautical mile prior to touchdown.

Figure VI-4 indicates an 11 PNdB peak-to-peak change in PNL expected at landing power. The accuracy of the estimates is shown by the shaded areas around the lines. With the accuracy estimates shown, the peak-to-peak noise level change that will result from the flight tests of the modified nacelles could be as much as 14 PNdB or as little as 6 PNdB.

The conditions selected for comparison of the noise levels during takeoff were a location 3.5 nautical miles from the start of the takeoff roll (brake release) and full takeoff thrust. Estimated instantaneous PNLs for the takeoff conditions are shown in Figure VI-5. The reference is again when the airplane is approximately directly overhead. The peak PNL from the modified nacelle occurs about three seconds after the peak PNL from the existing nacelle. Essentially, no change is indicated for the value of the peak instantaneous PNL, although the duration of the top ten PNdB of the predicted PNL history is less with the modified nacelles than with the existing nacelles. The shaded areas represent the same accuracy estimates shown in Figure VI-4.

The data shown in Figure VI-5 is for an aircraft at maximum gross takeoff weight. For airplanes taking off at
less than maximum gross weight -- probably almost all of the domestic flights and also most of the international flights -- there will be some reduction in the peak instantaneous PNL, since most of the airplanes will reach an altitude where safe thrust reduction can be made before reaching the 3.5 nautical mile point.

The variation in the reduction in peak PNL with distance from the threshold during landing approach is shown in Figure VI-6. The reductions are shown to a distance of seven nautical miles from threshold where the airplane is about 2,000 feet above the ground. The reduction is approximately constant to five nautical miles and then begins to decrease rather rapidly. No data are presented for the takeoff case because essentially no change was predicted for the peak PNL for airplanes at full takeoff thrust and at distances of 800 feet or more.

The variation with distance to the airplanes of the estimated peak instantaneous PNL's is given in Figure VI-7, for airplanes equipped with the existing modified nacelles. Data are presented for full takeoff thrust and for a landing thrust corresponding to maximum landing weight. The same trends noted previously are evident in Figure VI-7; namely larger reductions are obtained at the landing power setting than at the takeoff power setting, and the reductions
decrease as the distance the airplane increases, either directly under the flight path or to the side of the runway.

The data in Figure VI-7 also provide an indication of the changes in PNL that would be expected to the side of the airplane flight path in the vicinity of the airport. For example, at a point about 3,000 feet to the side of the runway (assuming that the airplane is just high enough that ground attenuation effects are not important), the PNL during takeoff at full takeoff thrust would remain unchanged at about 104 PNdB. During the landing approach, however, the PNL at 3,000 feet to the side of the landing path would be reduced from about 92 to about 84.5 PNdB. It is worthwhile to note that of those airport neighbors who are concerned with only approach noise the people exposed to the higher values of PNL will experience the large noise reductions.

Direct Operating Cost Estimates. Considerable data is required to predict the cost associated with a particular noise reduction technique. The data must include an estimate of a retrofit cost and a listing of the changes affecting an airplane's performance. It is, therefore, necessary to understand the economics of air transport operations.\textsuperscript{16}

"The costs associated with airline operation are broken down into two major categories: direct operating costs (DOC) and indirect operating costs (IOC). Indirect costs basically refer to those costs incurred during ground operations which do not directly affect the mechanical nature of the aircraft. A general outline of the type of activity which IOC represents is given below:

- Passenger service, (food, stewardesses)
- Aircraft servicing (cleaning)
- Traffic servicing (baggage handling)
- Reservations and sales
- General and administration
- Depreciation of ground facilities."

Notice that IOC is determined by the type of service which the airline wishes to extend to its customers; it does not represent the actual cost of operating the airfleet (i.e. keeping the planes in the air.) Indirect operating costs, therefore, need not be considered here.

Direct Operating Costs, on the other hand, refer to those costs incurred during actual aircraft operation. An outline of the factors which determine DOC are listed below.

**Total Flight Operations**
- Pilot Salary
- Co-Pilot Salary

**Total Maintenance**
- Airframe Maintenance
  - Labor
  - Materials
- Engine Maintenance
  - Labor
  - Materials
Applied maintenance burden (required to be reported under direct costs by the CAB)

**Total Depreciation**
- Airframe
- Airframe spares
- Engines
- Engines spares
- Propellers, rotors, transmission
- Electronic equipment.

DOC alone is affected by retrofit. An increase in direct costs includes both the non-recurring costs such as maintenance and added fuel consumption. For this particular retrofit modification the cost including parts and installation in 1972 dollars is estimated to be $545,500 per aircraft (4 new nacelles). Coupled with this are changes in airplane performance: empty operating weight is increased 332 pounds, cruise specific fuel consumption is increased 0.6 percent, maximum cruise thrust is reduced 2.1 percent, takeoff thrust is reduced by 2.35 percent, and range reduced 50 nautical miles.

A standard method for predicting the DOC of an aircraft is the Air Transport Association (ATA) method. The ATA method is useful because it allows the calculation of DOC changes incurred by such factors as added cost, increased weight, and decreased performance. The influence of these factors on DOC

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17 Pendley and Marsh, _loc. cit._
18 Ibid.
resulting from noise-reducing engine modification can, thus, be determined.

Poslusny, using the ATA method, reports increases in DOC resulting from the Douglas modifications based on the following assumptions: 19

- Depreciation period-airplane 12 years
- Depreciation period-nacelle 5 years
- Utilization variable
- Seats 135
- Initial Spares 20 percent
- Maintenance-nacelles $1.06/flight hour

Resulting changes in DOC are: 20

- Crew 0.02 percent DOC increase
- Insurance 0.38 percent DOC increase
- Fuel 0.40 percent DOC increase
- Maintenance 0.56 percent DOC increase
- Depreciation 4.38 percent DOC increase

Total 5.47 percent DOC increase

Additional crew costs result from the effect modifications have on time in climb. Lengthening it lowers block speed. Increased insurance costs are due to the added costs

19 Poslusny, op. cit., p. 82.
20 Ibid.
of the nacelles. Increased fuel expenditures are caused by higher specific fuel consumption and greater airplane weight. A 50 percent frequency increase of unscheduled inlet and exhaust duct maintenance and the new expense of acoustic lining replacement raised maintenance costs. Depreciation increases came from the added cost of retrofit if absorbed by the airlines.

For CTOL operations, LOC is approximately equal to DOC since,

\[(DOC+IOC) + \text{Profit/Average Load Factor} = \text{Fare},\]

if Average Load Factor equals 50 percent, then the percentage increase in fare that would be required to offset the cost of nacelle retrofit is \(5.47/4\) or a 1.4 percent increase.

In July 1970, two years after Poslusny finished his study, the FAA published the results of a study undertaken by the Rohr Corporation to provide the FAA with technical and economic information on acoustic treatment of low bypass turbo-fan engine ducts and nacelles.\(^{21}\) The basic study plan consisted

of applying a series of four retrofit nacelle configurations set by acoustic reduction criteria, and three acoustic materials for each configuration, to six aircraft. The resulting matrix of 72 design points was then subjected to engineering, cost and economic analysis. The economic analysis included a determination of the economic impact on fifteen airlines.

The acoustic criteria for the first of the four retrofit configurations studied was to reduce the fan noise to the level of the untreated primary exhaust noise on takeoff. The second configuration criteria was to reduce the fan noise to an intermediate level, the same achieved by the McDonnell Douglas Corporation for their NASA contract. 22

The third configuration criteria was to reduce the fan noise to the level of the untreated primary on both takeoff and approach. Configuration four was to provide maximum noise reduction including primary exhaust suppression.

The basic acoustic materials studied in the report were (1) a perforated plate bonded to a honeycomb core with an aluminum backing sheet; (2) a perforated plate bonded to a double honeycomb core with an aluminum backing sheet; and (3) a fibermetal bonded to an aluminum honeycomb with an aluminum backing sheet.

22 Pendley and Marsh, loc.cit.
Changes in thrust, drag, and weight were computed for all design points. The effect of thrust and drag were included in the determination of acoustic levels on takeoff and also on DOC. Airplane weight changes were also considered in the DOC analysis. The computation of the changes in direct operating cost was based on a modification of the 1967 ATA method.

A summary of major results from the Rohr study is shown in Table VI-5. The cost of retrofit was found to vary between $212 million and $1.246 billion. The percentage increase in total passengers fares required to offset the retrofit cost ranged between 0.08 percent and 0.40 percent.

In a general sense, the results of both Poslusny's investigation and the Rohr Corporation study show that the airlines would be faced with a relatively modest fare increase to completely offset the cost of a retrofit program, even for the more complex configurations considered in the Rohr study. Variance between the results of Poslusny's analysis and that conducted by the Rohr Corporation, is explained by at least two factors. First, the greater comprehensiveness of the Rohr
study and second, the sensitivity of results to changed assumptions in retrofit kit cost and depreciation schedule which a sensitivity analysis conducted as part of Rohr study revealed.

Timing of the retrofit process is an important issue. One engineering assessment of the retrofit process concludes it would require a series of steps through a time span of approximately five to six years to accomplish significant noise reduction for airplanes powered by low-bypass-ratio turbofans.\(^{23}\) The length of time is dependent on the degree of noise reduction required, the availability of the technology required, and the airplane models affected.

The process would begin with studies and tests, both model and full scale, to determine the configuration change necessary for each airplane model series to meet the noise reduction required that is economically reasonable, that is technologically practicable, and that would provide significant community relief. Testing would include wind tunnel tests for performance and airplane flutter; model tests for engine thrust and reverser performances; full-scale lining tests for noise absorption; full-scale ground rig testing for noise and performance data.

Once a configuration has been selected for retrofit of a given airplane model, the design would then be developed in detail and released for manufacture of parts. The first set of parts would be mounted on a ground test engine to evaluate design, performance, noise, safety, and durability. The first complete airplane set would be flown to certify the new configuration to FAA requirements for airworthiness and noise. Each variation of the engine nacelle configuration for each airplane model would also have to be evaluated, where different, to ensure FAA approval on all models affected.

Upon FAA certification of the retrofit nacelle and completion of service testing, kit parts would be made available to the airlines for installation.

An estimate of the timing of this process for retrofit is shown in Figure VI-8. The times are approximate and would vary due to the complexity of changes required.

In conclusion, with regard to current aircraft, retrofit of the existing fleet, at the approximate cost of $500,000 to one million dollars per aircraft, would cost only about $1-2 billion, or a fraction of the billions it would cost to convert land use at the world's major airports.24

24 ICAO, op. cit., p. 7.
The cost of retrofit, if financed by a fare increase, is imposed on the air passenger. No examination was made in either study of the airlines ability, either individually or collectively, to fund the initial cost impact of the retrofit programs considered. Chapter IX discusses a noise alleviation program which suggests a solution to this problem.

Operational Changes

Specification of flight procedures designed to reduce the noise level beyond airport boundaries and to limit the amount and frequency of exposure of affected land areas is another in-the-air solution. High altitude over water approaches, preferential runway criteria, variations in the flight profile, turns to avoid heavily populated areas, and new and relocated air traffic guidance equipment are specific measures employed to implement this solution.

NASA has conducted flight and simulation investigations to evaluate steep two-segment noise abatement landing-approach profiles. Precision common to conventional instrument landing approaches without an increase in pilot workload was required. The amount of noise reduction depended on the altitude of intercept of the two segments. Profiles

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with an intercept altitude of 400 feet, an acceptable altitude to pilots, resulted in a noise reduction along the centerline of 10 PNdB or more 1\frac{1}{2} nautical miles from the runway threshold and beyond.

Two segment landing approach profiles were examined using a modified Boeing 707. Improvements carried by this aircraft included a flight director modified for two-segment profiles, an auto throttle, and both longitudinal and lateral directional stability augmentation. Reservations about two-segment land approach profiles have been expressed by pilots.

Airspeed of a Boeing 707, or similar transport category aircraft, remains constant during landing. Exact speed is determined by aircraft configuration; (i.e., flap setting, gear up or down, etc.) and weight. If airspeed increases, the aircraft may not be able to come safely to a stop on the runway once touched down. If too slow, the aircraft is in danger of stalling.

On a normal three-degree glide slope with an approach of 140 knots, the specified rate of descent is 745 feet/minute.\(^{26}\) Pilot preferred touchdown rate is 400 to 500 feet

\(^{26}\) Rate of Descent Table, Low Altitude Instrument Approach Procedures, Department of Defense, St. Louis: Aeronautical Chart and Information Center. (Periodically updated.)
per minute. On a two-slope approach path, as illustrated in Figure VI-9, the aircraft's specified rate of descent between the outer and inner markers on a six-degree slope is approximately 1,500 feet per minute or twice that of an aircraft on a three-degree glide path.

The transition from a six-to-three degree glide slope at the inner marker, (400 feet) is a crucial maneuver. At this point with a descent rate of 1,500 feet/minute the aircraft is 16 seconds from the ground. Only 30 seconds remain before crossing the runway threshold. Complicated maneuvering is demanded of the pilot or his equipment as both glide slope and rate of descent must be rapidly and drastically adjusted.

NASA evaluation flights were flown under simulated instrument conditions in daylight and in near-ideal weather. Further tests were conceded to be necessary to examine requirements and operational limitations of two-segment approaches in an environment more representative of airline operations. The Airline Pilot's Association (ALPA) agrees that two-segment approaches are possible when the visibility is good, but points out that in year-round carrier operations unrestricted visibilities are more the exception rather than the rule. Present generation autopilots necessary in inclement weather are insufficient, pilots charge, to be trusted with a maneuver this critical. Further, autopilots include
insufficient provisions for pilots to monitor their performance. A six-degree glide slope puts a transport category aircraft near performance limitations. A malfunction of the autopilot at transition would jeopardize aircraft safety by making this demanding maneuver immediately essential to avoid crashing.

Accurate cost figures for the development and production of an autopilot of sufficient quality to warrant full pilot confidence could not be obtained. The cost would vary according to the number of units produced and the amount of development time available. The value of a major investment in such an autopilot is limited by the likely development of a technologically superior alternative. In ten years, a scanning beam microwave instrument landing system should be a reality, given its present rate of progress, making even an improved version of present equipment obsolete. This system will allow pilots to fly curved approach paths as opposed to present straight paths, with accuracy and relative ease. Approach paths similar to the one illustrated in Figure VI-10 may then be possible.

More rapid development of the scanning beam microwave ILS is possible given adequate financial backing for hardware development and testing. To present, the FAA financial backing needed to expedite development of this system has
not been forthcoming.

Noise abatement procedures involving overwater approaches and preferential runway criteria are not dependent on aircraft modification or special flight or ground equipment. At the airport in Boston and New York, such procedures have long been used.

Ex post facto examination of complaints from New York City residents about aircraft noise vividly demonstrates the effectiveness of this solution. Any change in operational measures has occasioned immediate vocal critical comment from newly affected community areas and marked an equally rapid decline in complaints from newly unaffected areas.

Opposition to operational measures came originally from carrier management, who questioned their legality, and from airline pilots who objected on grounds of safety. Numerous legal arguments that could be made on both sides of the issue were heard. Those questioning PONYA's stand on noise abatement operating procedures in 1960 made these chief points in opposition. 27

1. Control of air traffic is exclusively a function of the FAA.

2. PONYA rules, by curtailing air traffic, constitute an undue burden on interstate commerce.

27 New York Times, 9 November 1960, p. 70. col. 5.
3. The rules affect the safety of jet operations and PONYA officials are not safety experts.

Although at the time The Port of New York Authority did not detail its legal justification for its stand, among the arguments presented in justification are:

1. It is the landlord at the New York airports. Compliance with its rules is a condition of the contracts under which the airlines use the facilities.

2. The issue is not one of safety, but of noise. Noise is a nuisance to nearby communities. The state has the power to protect communities against such nuisances and PONYA is an agent of the state.

3. A landlord must protect himself against possible legal action from his neighbors.

Carrier managements, growing sensitive to adverse public opinion caused by aircraft noise, have shifted slowly to their present position of favoring noise reducing operating procedures. When these procedures are designed in consideration with the pilot's workload at takeoff and landing they have been willing to comply.

No cost information on preferential and priority use systems is available. DOC would be affected to the extent of longer flight and taxi times.
Also, in New York and Boston, for example, the present level of opposition to aircraft noise exists with special operating procedures in regular use. Such procedures only lower noise a limited amount and cannot be used when certain weather conditions exist.

Summary

Finally, in summary, a number of measures that are or will be available to improve the environmental compatibility of existing or new airports have been described and evaluated. All related to abatement of noise and, therefore, were primarily for human social, physiological, and psychological benefit as well as economic benefit to some degree.

The effectiveness of most measures to reduce noise exposure near airports was poor. Zoning was largely unsuccessful in excluding noise sensitive land uses from the area surrounding the airport. While acoustic conditioning of all structures exposed to excessive aircraft noise would produce significant protection, the cost of this conditioning was found to be excessive. Also, out-of-door activities would remain affected. Purchase of all noise affected land was found infeasible. Construction of new airports, informed opinion indicated, may be considered entirely impossible near urban centers and increasingly less feasible in remote areas.
Altree argued in favor of time limited avigation easements because the method will compensate for the gross injustice of forced transfer of wealth perpetrated on those subjected to aircraft noise and will cause airport operators, air carrier management, and engine and airframe manufacturers to search for ways to curb noise. The method does not in any way curtail noise or its effects.

Permanent noise easements were found lacking in utility due to their considerable expense, and lack of effect on present noise levels. Further, they limit future incentive to cut noise levels at the source.

The analysis indicated three methods were potentially capable of producing significant reduction in noise exposure:

. Retrofit engines with acoustically-treated nacelles.
. Re-equip fleet with high-bypass-ratio engines.
. Implement steep two-segment landing approach profiles.
. Noise abatement procedures on power reductions and terminal area flight paths.

A retrofit program able to reduce takeoff noise by up to 14 PNdB offers a substantial improvement over present circumstances. Since sound is measured on a logarithmic scale,
every reduction of 10 dB represents a halving of the noise. A
PNdB reduction of 20, achievable with a high-bypass-ratio eng-
ine would half present noise levels and then half them again.
Another 10 PNdB reduction is potentially realized by implement-
ing steep two-segment landing approach profiles.

A total reduction of 24 PNdB is, thus, possible from
a combination of engine retrofit and approach profile modifica-
tion. Combining the latter program to re-equip existing turbo-
jet aircraft with a high-bypass ratio engine is capable of
producing a 30 PNdB reduction in noise levels and possible
noise reductions. Additionally, diversion of air passengers to
another travel mode have still to be evaluated. Chapter VII
considers this issue.
Figure VI-1
PERCEIVED NOISE LEVEL CONTOURS FOR TURBOJET AND TURBOFAN AIRCRAFT LANDING

Figure VI-2

EFFECT OF BYPASS RATIO ON JET NOISE

Figure VI-3

EFFECT OF ROTOR-STATOR SPACING ON COMPRESSOR NOISE

Figure VI-4

ESTIMATED PERCEIVED NOISE LEVEL DURING FLYOVER

Altitude = 370 Ft.; Landing Power

Figure VI-5

ESTIMATED PERCEIVED NOISE LEVEL DURING FLYOVER

Takeoff Power; 3.5 n.mi. from Brake Release Maximum Gross Weight

Figure VI-6

ESTIMATED PERCEIVED NOISE LEVEL REDUCTIONS
UNDER LANDING APPROACH PATH

Maximum Landing Weight

Figure VI-7
ESTIMATED PERCEIVED NOISE LEVELS OUTDOORS
DC-8 With JT3D Engines

Figure VI-8

NACELLE RETROFIT SCHEDULE

Figure VI-9

ONE AND TWO SEGMENT LANDING APPROACH PROFILES

Point of Transition
Altitude 400'

Outer Marker  Inner Marker  Runway

+6 1 mi.
Figure VI-10

POSSIBLE APPROACH PATH USING SCANNING BEAM
MICROWAVE INSTRUMENT LANDING SYSTEM

Horizontal View

Noise Sensitive Area Runway

Present Approach Path

Vertical View

Curved Approach Path
### Table VI-1

**COST AND NOISE TRANSMISSION LOSS**

<table>
<thead>
<tr>
<th>Sound Reduction</th>
<th>Cost For Residential Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inherent</td>
<td>Base Cost</td>
</tr>
<tr>
<td>Add-on Acoustic Conditioning 10 dB (Max)</td>
<td>10dB max @ 1% dB</td>
</tr>
<tr>
<td>Storm Windows</td>
<td>2%</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>Base Cost + 22%</strong></td>
</tr>
<tr>
<td></td>
<td><strong>42 dB</strong></td>
</tr>
</tbody>
</table>

Table VI-2

NUMBER OF PEOPLE LOCATED WITHIN CURRENT AND PROJECTED ZONES OF HIGH NOISE EXPOSURE - NEF 30

<table>
<thead>
<tr>
<th></th>
<th>Los Angeles (International)</th>
<th>Chicago (O'Hare)</th>
<th>New York (JFK)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>210,200¹ 310,800²</td>
<td>236,000 432,600³</td>
<td>665,700⁴ 1,747,600</td>
</tr>
</tbody>
</table>

Notes:

1 Estimate based on County records for 1967.
2 Estimate by author McGrath.
3 Based on Chicago Area Transportation Study projection for 1980.
4 Estimate based on records available for 1963.

Source: Dorn C. McGrath, "Environmental Considerations and the Metropolitan Airport System." SAE Paper 700253.
Table VI-3
COSTS FOR ACOUSTIC CONDITIONING OF RESIDENTIAL STRUCTURES IN THREE U.S. CITIES

<table>
<thead>
<tr>
<th>City</th>
<th>Year</th>
<th>Population</th>
<th>Families</th>
<th>Dwelling Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Los Angeles</td>
<td>1963</td>
<td>210,200</td>
<td>57,900</td>
<td>57,900</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>1975</td>
<td>312,800</td>
<td>86,200</td>
<td>86,200</td>
</tr>
<tr>
<td>Chicago</td>
<td>1965</td>
<td>236,000</td>
<td>65,000</td>
<td>65,000</td>
</tr>
<tr>
<td>Chicago</td>
<td>1975</td>
<td>432,600</td>
<td>119,000</td>
<td>119,000</td>
</tr>
<tr>
<td>New York</td>
<td>1965</td>
<td>665,700</td>
<td>183,400</td>
<td>183,400</td>
</tr>
<tr>
<td>New York</td>
<td>1975</td>
<td>1,747,600</td>
<td>481,400</td>
<td>481,400</td>
</tr>
</tbody>
</table>

1 Based average of 3.63 persons/family.

2 Assuming one-family/dwelling unit.

Table VI-4

IMPROVEMENT OVER TODAY'S NOISE LEVELS (Large Four-Engine Transports)

<table>
<thead>
<tr>
<th></th>
<th>Takeoff</th>
<th>Approach</th>
<th>Sideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>747 Reduction Relative to Today's Higher Levels (EPNdB)</td>
<td>3-9</td>
<td>6-9</td>
<td>5-8</td>
</tr>
</tbody>
</table>

Table VI-5

SUMMARY OF MAJOR RESULTS
FROM THE ROHR CORPORATION REPORT

<table>
<thead>
<tr>
<th>Configuration</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fifteen Airline</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average DOC Change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1978) (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smallest (727)</td>
<td>0.7</td>
<td>1.6</td>
<td>2.4</td>
<td>3.7</td>
</tr>
<tr>
<td>Mean</td>
<td>1.0</td>
<td>2.4</td>
<td>3.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Largest (737-200)</td>
<td>2.0</td>
<td>3.1</td>
<td>4.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Fare Increase Required</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(1978) (%)</td>
<td>0.8</td>
<td>0.08</td>
<td>0.30</td>
<td>0.40</td>
</tr>
</tbody>
</table>

CHAPTER VII

NOISE ALLEVIATION THROUGH TRAFFIC DIVERSION

Introduction

The methods of reducing aircraft noise at the source described in the previous chapter, provide an immediate reduction in aircraft noise levels. Another way to reduce aircraft noise is to reduce the number of aircraft movements. This can be accomplished by diverting air passengers to other modes of transportation.

Diversion to other modes is studied in this chapter with dual objectives. The first objective determines the feasibility of diversion as a noise reduction technique. Unless diversion potentially reduces noise levels significantly, the feasibility is doubtful.

At the same time, the feasibility of developing and operating a diversionary system is sensitive to its economic and environmental costs. The second objective of this chapter is to examine two alternative systems, high-speed rail, and V/STOL, to tentatively determine their economic and environmental feasibility.
Diversion as a Noise Reduction Technique

The effectiveness of changes in aircraft operating procedures and aircraft hardware in reducing noise exposure near airports can be evaluated in various ways. One method determines the relative changes in land areas affected by high noise levels. Work by Bishop and Horonjeff has explored the changes in land area falling within the NEF 30 and 40 contours that result from such changes. They constructed sets of NEF contours for two different aircraft types operating from a single-runway airport. The number of operations per day was varied from 200 to 1,000. The changes included power cutbacks after takeoff; two segment approaches, and retrofit of four-engine turbofan aircraft with acoustically lined nacelles or re-equipping aircraft with a "quiet engine."

According to their report, there was a significant reduction in the land area exposed to NEF 30+ and 40+ noise environments by the introduction of either lined nacelles or quiet engines. Operational changes alone generally resulted in only moderate reductions (and even some increases) in the land areas falling within the NEF 30 and 40 contours. These results

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are illustrated in Figure VII-1.

Figure VII-1 shows the land areas in the takeoff sector falling within the NEF 30 and 40 contours plotted as a function of the number of takeoffs per day (exposed areas are plotted on a logarithmic scale in Figure VII-1. Base line references are 100, 200, and 500 landings and takeoffs per day;(i.e., 200, 400, and 1,000 operations per day.) Although the relative ranking of the effectiveness of various changes is quite consistent and generally remains unchanged as the number of operations is varied, there is some variation in effectiveness of the changes with the number of operations. The fact that the curves are broken and are not parallel, indicates this. The relative effectiveness of the various noise reduction changes is influenced by the number of operations for a number of reasons. The aircraft takeoff profiles are not the same for the different aircraft classifications and the EPNL curves for the different aircraft classifications are not parallel, hence the importance of a given class of aircraft in determining a given NEF value may slowly change with the number of operations.

For segmented takeoff or landing profiles, such as the power cutback after takeoff (or the two-segment approach), the choice of the distance at which the power cutback (or change in glide slope angles) is made will influence the shape of a curve showing the relative effectiveness of the change vs. number of operations. For example, with only small number of operations, the NEF 40 contour may well close before the 3.5 nautical miles power cutback point is reached, hence the land area within the NEF 40 contour would not be affected by the power cutback procedure. However,
to the reduction in land areas exposed to NEF 30 or 40 noise environment by the introduction of either lined nacelles or the quiet engine, an important trend denoted by these results is the potential effectiveness of diverting air passengers to other modes as a method of reducing aircraft noise exposure.

**Candidate Systems**

Two diversionary systems are studied in this chapter: (1) Intercity rail transportation, and (2) STOL or VTOL aircraft operating in a separate airways systems.

**Diversion to Intercity Rail Transportation.** According to the PONYA 1963 survey of the domestic air passenger market, trips of under 250 miles accounted for 27 percent of all domestic trips originating in New York. ³ Two Northeast Corridor cities ranked first and third in flight destinations within this category: Boston, with 11 percent of total trips, and Washington, with 8 percent. Boston and Washington accounted for 71 percent of the trips in this 250-mile range. The proportion of plane movement involved is higher. The reason

for this discrepancy lies in the route structure of the airlines: a large share of passengers on board a plane whose first stop out of New York is, for example, Philadelphia, are not destined for Philadelphia but rather for points beyond. Reductions in passenger demand to these cities does not necessarily lead to proportional reductions in plane movements.

Still, high-speed intercity rail service is capable of competing with air and could divert a substantial proportion of the short-haul air traffic. How much of the market a rail system can divert will vary with the type of system developed. In the Northeast Corridor Project, three conventional rail alternatives, representing successively higher performance capabilities and higher costs, were evaluated. Table VII-1 summarizes the characteristics of each alternative. Market shares of the three alternatives DEMO, HRSA, and HRSC, were calculated to be 8 percent, 12 percent, and 15 percent respectively.

To determine what these potential market shares mean in terms of reduced air passenger demand, the discussion had to consider the role of the highway transportation. Highway's

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share of the Northeast Corridor travel market was 76 percent of total intercity passenger miles with 67.6 percent of these provided by automobiles and 8.4 percent by bus.5

By 1975, the Corridor project anticipates that both automobile and bus shares will be larger. Automobile travel is expected to increase its market share from 68 to 73 percent, and bus from 8 to 9 percent. During the same period, intercity passenger miles by air are expected to decrease from 11 to 9 percent.6

Potentially, rail transportation is capable of diverting a proportion of passengers from trips between Northeast Corridor cities. Yet, even if half the air travelers presently flying short-haul out of New York were to switch to rail transportation, the difference would be only 13.5 percent in the total domestic air passenger volume.

Aviation Systems. Two more promising sources of diversion than high-speed rail are STOL (Short Takeoff and Landing) and VTOL (Vertical Takeoff and Landing) systems. STOL and VTOL systems have a number of possible advantages in short-haul and medium-haul markets. V/STOL can make inroads into the entire short and medium-haul markets -- not just the major

5 Ibid. p. 36.
6 Ibid.
cities in the Northeast Corridor. All destinations within 250 miles of New York, for example, could conceivably be served by a V/STOL system. Destinations within 250 miles of New York City currently account for 23 percent of all domestic and overseas air passenger trips from the city and for 43 percent of all aircraft movements. Part of the difference between these two numbers is explained by the scheduling effect explained above. The rest of the difference is accounted for by small average plane size on routes to small, close-in cities. Diversion could, thus, be greater than 23 percent and might come to close to 43 percent. Further, these systems could provide service to locations more convenient to travelers and could thereby provide short-distance air travelers with faster and more convenient air service.

The potential of VTOL and STOL systems serving the New York Region were evaluated by T. F. Kirkwood and S. L. Kattan, as part of the studies of air transportation systems carried out by the RAND Corporation for PONYA. They concluded that: ".....by 1980, a downtown VTOL port operating in competition with the major airports might attract on the order of 10,000

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passengers a day (about nine percent of the total air passenger traffic in the New York area)."

Air carrier arrivals at the region's airports would be reduced by more than 200, or about 20 percent, per day in 1980. Discounting CTOL services between New York and those cities most efficiently served by V/STOL could attract as many as 30,000 passengers. CTOL use of the region's three major airports would be reduced by roughly 40 percent.

The Northeast Corridor Transportation Project conducted a comprehensive analysis of inter-city passenger transport alternatives for the Boston-Washington Corridor. The authors of the report concluded that a STOL system could be developed by 1975 that would account for twelve percent of the Corridor inter-city travel market (as a percentage of passenger miles) as contrasted with three percent for CTOL. Without STOL, their analysis suggests, CTOL will account for approximately nine percent of the inter-city passenger miles in the Corridor in 1975. 8 Moreover, the analysis indicates that a STOL system would reduce the number of passengers using New York's CTOL airports for

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8 This figure is based on alternative 11 (of the nine studied in the Northeast Corridor Project) which consists of auto, bus, CTOL, demonstration rail (expanded turbotrain and metroliner service), and STOL.
trips to Corridor cities by two-thirds. 9

A great deal of enthusiasm for STOL systems is apparent in the Northeast Corridor Project and RAND study for PONYA. STOL also figures prominently in the Regional Plan Association's July 1969 assessment of proposals for a fourth major airport in the New York region. The authors of the Association's report observe that Eastern Air Lines and American Airlines have been testing a commercially available STOL aircraft, the Breguet 941 which seats 64 passengers and cruises at 250-280 miles per hour. The report concludes that STOL aircraft are likely to be "a more significant source of diversion than either the peripheral airports or high-speed conventional rail." 10

In spite of the evident enthusiasm expressed for STOL systems, many problems must be solved before such systems begin operations. For example, many aviation experts doubt the reliability and safety of STOL systems because of control problems during high winds. Others believe that STOL enthusiasts have underestimated the difficulties of providing the


required independent air navigation system. Further, STOL metroport requirements begin with a basic 16.5 or 29.5 acre requirement for the one or two runways they require, plus an additional acre per loading gate which is not easy to acquire in the core of the New York region or in other cities of the Atlantic Seaboard.¹¹

Many of these STOL critics are VTOL enthusiasts, who see great promise in VTOL to develop safe and effective short- and medium-range air systems. So far, the costs of VTOL aircraft have been unreasonably high for airline application, but these higher costs may be offset by the minimal land requirements of VTOL terminals -- a VTOL metroport will require only about one acre per pad or loading gate -- and the ability of VTOL aircraft to enter high-density urban areas directly. Further, it is reasonable to assume that some of the technological and cost barriers will be broken with larger and faster aircraft.

The total investment for a hypothetical "Airbus System" serving major city centers and suburban areas in the Northeast Corridor was studied by the MIT Flight Transportation Laboratory in "A Systems Analysis of Short-Haul Air

Transportation.\textsuperscript{12} Both STOL and VTOL were considered. Results of this work are summarized in Table VII-2. An 80-passenger air vehicle was hypothesized. The mix of each aircraft and the fleet required are listed in Table VII-3. A tiltwing design aircraft was selected to determine typical VTOL vehicle and terminal requirements.

Total airbus system investments are $479.5 million for a system using tiltwing VTOL aircraft, and $882.2 million for a comparable STOL system. The difference in cost is explained by the greater vehicle, terminal, and land acquisition costs associated with the STOL system.

Environmental Costs: Reduced or Transferred?

Both VTOL and STOL are ways to reduce the exposure to CTOL aircraft noise. However, is exposure to noise actually reduced by this diversion or will the noise simply be transferred to the urban subpopulation living or working near proposed VTOL and STOL terminal locations?

The answer to this question is dependent upon the kind of short-haul air transportation system that is developed. In a 1968 Master's Thesis, Lindley studied the impact of the noise generated by three, successively quieter, 80-passenger

\textsuperscript{12} A Systems Analysis of Short-Haul Air Transportation, MIT Flight Laboratory, Report TR-65-1 (August 1965).
VTOL aircraft. Lindley plotted VTOL noise signatures to describe the noise exposure resulting from near-city rotary wing aircraft service in Boston. The three vehicles evaluated are listed below:

2. Quiet Tilt Wing - 100 PNdB at 250 feet.
3. Quiet Helicopter - 90 PNdB at 250 feet.

Ground level noise contours for these three aircraft, based on a 200-foot vertical rise followed by a fifteen degree climb angle were constructed. Figures VII-2 and VII-3 depict these contours. Contour lines are five PNdB apart and the outside line represents 80 PNdB.

Lindley plotted the approximate noise contours that would be generated by the noisy 80-passenger helicopter flying over the railway yards in Cambridge to a vertiport located near the Charles River Dam. Typical helicopter noise levels that would be measured in the surrounding communities are:

<table>
<thead>
<tr>
<th>Location</th>
<th>Noise Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Cambridge (residential)</td>
<td>84 PNdB</td>
</tr>
<tr>
<td>Charleston (residential)</td>
<td>85 PNdB</td>
</tr>
<tr>
<td>East Sommerville (residential)</td>
<td>85 PNdB</td>
</tr>
<tr>
<td>Beacon Hill (residential)</td>
<td>90 PNdB</td>
</tr>
<tr>
<td>Massachusetts General Hospital</td>
<td>87 PNdB</td>
</tr>
</tbody>
</table>

Estimated daytime background noise levels are 65, 65, 65, 60, and 60 respectively. Each value drops about ten PNdB at night. Using a Composite Noise Rating Correction Chart and assuming greater than twenty operations per hour during the day, five peak operations at night, and full flight path utilization, Lindley calculated the following CNR values:

<table>
<thead>
<tr>
<th>Location</th>
<th>CNR Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Cambridge</td>
<td>100</td>
</tr>
<tr>
<td>Charlestown</td>
<td>100</td>
</tr>
<tr>
<td>East Sommerville</td>
<td>100</td>
</tr>
<tr>
<td>Beacon Hill</td>
<td>105</td>
</tr>
<tr>
<td>Massachusetts General Hospital</td>
<td>103</td>
</tr>
</tbody>
</table>

Day and Night CNR Values.

The indicated CNR values are marginal, both during the day and at night in the first three communities. Neither on Beacon Hill, nor at Massachusetts General Hospital will the CNR values be acceptable. If VTOL aircraft of this noise level, 110 PNdB at 250 feet, are to be used, location of a vertiport near the Charles River Dam is not recommended due to the excessive noise that would be generated. Other locations in the immediate vicinity of Boston proved to be just as bad for operations with this noisy aircraft according to Lindley's continuing analysis.

Reducing aircraft noise by ten PNdB, corresponding to a quiet tiltwing vehicle causes considerable change, reports Lindley. Corresponding background noise levels, aircraft
PNdB levels, and CNR values for the areas discussed before are:

<table>
<thead>
<tr>
<th>Area</th>
<th>Background (day)</th>
<th>Aircraft Noise</th>
<th>CNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Cambridge</td>
<td>65 PNdB</td>
<td>80 max PNdB</td>
<td>95 max</td>
</tr>
<tr>
<td>Charlestown</td>
<td>65 PNdB</td>
<td>80 PNdB</td>
<td>95</td>
</tr>
<tr>
<td>East Sommerville</td>
<td>65 PNdB</td>
<td>80 PNdB</td>
<td>95</td>
</tr>
<tr>
<td>Beacon Hill</td>
<td>60 PNdB</td>
<td>83 max PNdB</td>
<td>98 max</td>
</tr>
<tr>
<td>Massachusetts General Hospital</td>
<td>60 PNdB</td>
<td>75 PNdB</td>
<td>90</td>
</tr>
</tbody>
</table>

On the basis of these CNR values, Lindley concludes no serious complaints are to be expected from communities north of the Charles River, but some complaints are still possible from Beacon Hill and Massachusetts General Hospital.

Lindley's final noise contour plot was for the quiet helicopter on the same site. Flights are possible with this vehicle north over the railyards, east up the Charles River, and west over Logan Airport. Aircraft altitude over the airport would be in excess of 4,000 feet based on a fifteen-degree climb or descent angle. This is well above any Logan traffic. Due to the low-generated noise levels, no complaints are expected from any of the surrounding communities or the hospital. Noise levels are comparable to those produced by the Bell Jet Ranger helicopters of the now defunct Air General, Inc., which flew regularly up and down the Charles River.
Continuing his test of sites, Lindley found the quiet helicopter able to land without undue disturbance at another site near downtown Boston, South Station. Sites over highway interchanges, such as those along Route 128, a Boston circumferential interstate highway, were also possible with the quiet helicopter.

In a 1968 FTL memo, Professor Rene Miller examined the changes in DOC to be anticipated if VTOL aircraft are to be designed to reduce noise level rather than for minimum DOC. The three main contributions to noise are the engine, the tail rotor, and the main rotor. According to Miller:

"The noise generated by the first two may be reduced to values below the rotor vortex noise level without any significant change in DOC. Reducing rotor noise, however, involves greater penalties. The summary curves of Figure VII-7 indicate a general trend of about five percent change in DOC for every five dB reduction in noise for the tilt-wing aircraft, and a somewhat greater penalty for the helicopter, except that, with the higher solidity rotors, an additional two to three dB reduction may be realized with the helicopter by slowing the rotor during hover and low speed within the limits of free turbine speed change capability."

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15 Ibid., p. 1.
Lightly loaded configurations should be capable, Miller states, of operating at dB levels of the order of 80 at 300 feet -- comparable to the quiet helicopter with which Lindley worked. Cost changes, concludes Miller, will be trivial.

This view of costs is understandable given the high indirect costs (IOC) associated with short-haul air travel. For CTOL aircraft, the DOC generally equals the IOC. An increase of ten percent in DOC results in a five percent increase in total costs. For short-haul aircraft, the IOC significantly exceeds the DOC. Minor variations in DOC do not cause a large increase in total costs.

Lindley's work indicates that a VTOL system utilizing a quiet helicopter can operate from a near-city center location in a large, densely-populated city at or below the existing ambient noise level.

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16 IOC dominance results from the multiple hops characterizing short-haul operations. The role of functions, such as reservations, sale of tickets, and terminal passenger services is magnified.
Other work on VTOL by Miller has indicated that the operation of a VTOL system utilizing quiet helicopter is financially feasible.

Both VTOL and STOL deserve serious study as ways to reduce aircraft noise exposure and increase the quality and quantity of inter-city travel. Presently inhibiting the development of a V/STOL system is a cycle of inaction. Aircraft manufacturers are reluctant to assume the risk of developing the special type of transport needed for short-haul use without air carrier orders and some assurance of governmental certification. Air carriers are reluctant to place orders for aircraft without some assurance of routes, suitable airports, and a suitable air traffic control system. Local communities are reluctant to provide new airports or allow the use of existing ones, because of the anticipated noise and pollution or because the advantages of the service are not readily apparent.

Early realization of the benefits from V/STOL will require a strong central focus with adequate funds and sufficient authority to support the research, development, planning, and implementation of these systems. The federal government is capable of playing such a role. A justification for the federal government assuming this role is presented in the final chapter.
Figure VII-1

VARIATION IN TAKEOFF SECTOR LAND AREAS WITHIN NEF 30+ AND NEF 40+ CONTOURS WITH NUMBER OF TAKEOFFS

Number of Takeoffs Per Day (Continued)
Figure VII-1
(Continued)

See Following Page For Explanation of Aircraft Mixes and List of Changes in Operations and Aircraft Characteristics.
Figure VII-1 (Continued)

AIRCRAFT MIXES

Mix A has a relatively high proportion of two-and three-engine turbofan aircraft and a significant proportion of large four-engine turbofan operating at relatively short ranges (less than 2,000 nautical miles). It is representative of the mix of aircraft at large midcontinent airports -- Chicago O'Hare Airport, for example.

Mix B includes a relatively high proportion of large four-engine turbofan aircraft operations over long ranges. The proportion of two- and three-engine turbofan aircraft is relatively small. This mix is typical of airports handling many inter-continental flights -- New York J. F. Kennedy Airport, for example.

LIST OF CHANGES IN OPERATIONS AND AIRCRAFT CHARACTERISTICS

E: Recquip four-engine turbofan aircraft with a "quiet" engine, currently under study by NASA.

D-1: Retrofit of acoustically lined nacelles to four-engine turbofan aircraft.

B: Power cutback after takeoff -- A power cutback to a 6% climb gradient at a distance of 3.5 nautical miles from start of takeoff roll, or, a power cutback to a 6% climb gradient at an altitude of 1,000 feet if the aircraft cannot reach 1,000 feet altitude at 3.5 nautical miles from start of takeoff roll.
Figure VI-2
PERCEIVED NOISE LEVEL CONTOURS
FOR 80-PASSENGER HELICOPTER BASED ON CURRENT DESIGN PRACTICES
200 FOOT VERTICAL RISE PLUS 15° SLOPE

Figure VII-3

PERCEIVED NOISE LEVEL CONTOURS FOR
80-PASSENGER QUIET TILT WING AND QUIET HELICOPTER
200 FOOT VERTICAL RISE PLUS 15 DEGREE SLOPE

Figure VII-4
COST PENALTIES FOR QUIET VTOL AIRCRAFT

Notes:
1. DOC's in the ranges indicated are those which when combined with IOC's anticipated in A Systems Analysis of Short-Haul Air Transportation result in an Airbus system capable of total costs comparable to those of the present air system.

2. FTL has estimated direct operating costs below 2¢/available seat mile over stage lengths between 50 and 200 miles. Advances in technology during the 1970s can potentially result in DOCs below 1¢/available seat mile for a system operating after 1980.
Table VII-1

CONVENTIONAL RAIL ALTERNATIVES

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description of Improvements</th>
<th>Speed</th>
<th>Capital Cost of Improvements</th>
<th>Annualized Surplus</th>
<th>Market Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEMO</td>
<td>Expanded version of present high speed service.</td>
<td>125 mph (top) 72 mph (avg)</td>
<td>$70 Million</td>
<td>$83 Million (in 1975).</td>
<td>8%</td>
</tr>
<tr>
<td>HSRA</td>
<td>High Speed rail on existing right-of-way.</td>
<td>150 mph (top) 109 mph (avg)</td>
<td>$1.6 Billion</td>
<td>Subsidy of $27 Million per year required in 1975. Commercially viable 1985-1990.</td>
<td>12%</td>
</tr>
<tr>
<td>HSRC</td>
<td>High Speed rail on new right-of-way.</td>
<td>N.A. 200 mph (avg)</td>
<td>$2.6 Billion</td>
<td>Subsidy of $67 Million per year in 1975.</td>
<td>15%</td>
</tr>
</tbody>
</table>

Source: Northeast Corridor Transportation Study Report.
Table VII-2
TOTAL AIRBUS SYSTEM INVESTMENTS
(Northeast Corridor Case Study)

<table>
<thead>
<tr>
<th>Category</th>
<th>VTOL</th>
<th>STOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Vehicles - VTOL (Tilt Wing)</td>
<td>$250.0</td>
<td></td>
</tr>
<tr>
<td>- STOL</td>
<td></td>
<td>$303.0</td>
</tr>
<tr>
<td>Ground Handling Equipment</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maintenance Facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Hangars</td>
<td>3.2</td>
<td>3.2</td>
</tr>
<tr>
<td>- Airframe Overhaul Base</td>
<td>12.0</td>
<td>12.0</td>
</tr>
<tr>
<td>- Engine Overhaul Base</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Terminal Facilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- VTOL System</td>
<td>93.1</td>
<td></td>
</tr>
<tr>
<td>- STOL System</td>
<td></td>
<td>175.0</td>
</tr>
<tr>
<td>Controls</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Land</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- VTOL System</td>
<td>89.2</td>
<td></td>
</tr>
<tr>
<td>- STOL System</td>
<td></td>
<td>357.0</td>
</tr>
<tr>
<td>Headquarters Building</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>and Computer System</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total System Investments</td>
<td>$479.5</td>
<td>$882.2</td>
</tr>
</tbody>
</table>

Source: A Systems Analysis of Short-Haul Air Transportation, MIT Flight Transportation Laboratory, 1965.
Table VII-3
AIRBUS SYSTEM FLEET REQUIREMENTS
(Northeast Corridor Case Study)

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Cost/Aircraft ($Mill)</th>
<th>Required Fleet Size *</th>
<th>Total Fleet Cost ($Mill)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilt Wing</td>
<td>3.82</td>
<td>65</td>
<td>250.0</td>
</tr>
<tr>
<td>Jet Lift</td>
<td>2.83</td>
<td>60</td>
<td>170.0</td>
</tr>
<tr>
<td>Helicopter</td>
<td>2.84</td>
<td>120</td>
<td>340.8</td>
</tr>
<tr>
<td>STOL</td>
<td>2.52</td>
<td>120</td>
<td>303.0</td>
</tr>
</tbody>
</table>

*Fleet size varies because block speeds of the aircraft differ.

Source: A Systems Analysis of Short-Haul Air Transportation, MIT Flight Transportation Laboratory, 1965.
Economics of Environmental Pollution

The economics of environmental pollution are rooted mainly in the dichotomy between social costs and individual costs. The fundamental economic considerations are relatively straightforward, but the practical solution to a specific case, such as aircraft noise, is complex. Moreover, attempts to cope with problems associated with environmental control frequently challenge cherished beliefs held by some to be fundamental to the American way of life. While everyone is in favor of improving the quality of life, the consensus becomes fragmented when specific paths to the goal are proposed.

The major uncertainty remaining for this dissertation to address is how the costs of controlling noise pollution will be allocated between the government (Federal, State, and Local) and the private sector (business firms and consumers.) The purpose of this chapter is to explore the issue of pollution economics and costs. The objective of the first Section is to put the problem of pollution into the economists framework. In the second Section, the objective is to identify mechanisms for coping with environmental pollution. The objective of the third and final Section is to apply the
principles of regulation and control to the problem of aircraft noise.

The Concept of Externalities. To a large extent, the popular controversy over airport noise is a lay controversy about a group of economic concepts known to economists as externalities. Although there is confusion and disagreement in the technical economic literature about the meaning and significance of these concepts, there is sufficient agreement to explain these concepts and apply them to airports.

The costs imposed by a business activity for which it is not required to pay (or conversely benefits for which it is unable to charge) are usually discussed in economics as the dichotomy between individual (i.e., private) and social costs. Individual costs are those that the firm cannot avoid incurring in producing its product; the social costs are those which are not borne by the producer. Industries giving rise to such dichotomies are those in which at some point in the production process wastes are discharged into the air or the water. The wastes impose a cost on others, by polluting the air or water supply of persons further downstream or creating additional cleaning and health costs or noise for residences in the vicinity of the factory or airport. These added costs are labeled, among other things, external diseconomies, or simply externalities.
Applying this concept to airports, it is apparent that if airport noise lessens the utility and market value of a residence and the air transport industry is not required to compensate the owner, the loss of value is an external cost of the industry. An argument is advanced by the industry against internalizing the costs of noise. The argument runs as follows:¹ The establishment or expansion of air transport services in a community is "in the public interest;" it brings enormous values and public benefits to the community. Witness the intensity with which communities petition and lobby for additional air service. To the extent that air transport also imposes losses in the community in the form of noise, these costs are comparable in kind to the community benefits and can be offset against them. The benefits exceed the costs; hence, the costs may be disregarded. To impose the costs on the industry rather than to leave them on the community to which enjoys the benefits would be "unfair", and it would hamper growth of the industry or even destroy it, thus preventing the industry from conferring further benefits on the community.

The argument is fallacious because it does not distinguish between externalities and private gain.² The gains derived from air transportation flow primarily to the customers

² Ibid., p. 25.
of the air transport industry -- to those who fly as passengers and ship products by air. To a lesser degree, some of the benefits are passed on to the customers of air transport. Thus, with some time lag and considerable dilution, the benefits of air transportation are fairly widely dispersed among the direct and indirect users of air transport.

In contrast, aircraft noise, a negative externality, is imposed with great concentration in the vicinity of the airport.

There is no necessary correlation between the identity of those who benefit from air transport and those upon whom this externality falls. There is even less correlation between the amount of benefit received and the externality imposed. To treat these distinct impacts as if they could be offset against one another is grossly inequitable to those who suffer the imposition of external losses.

**Effect of Externalities.** One important effect of externalities is to warp the allocation of productive resources. Joseph Scherer notes that:

> "In a free market economy, consumers and producers choose among goods and services on the basis of relative prices and usefulness. Changes in relative prices, reflecting supply conditions and market demand for foods, serve as signals for producers to increase, maintain, or reduce

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output, and this promotes an efficient allocation of resources. However, an efficient allocation of the factors of production presupposes that the prices of goods include their full costs of production. In the case of goods produced under conditions giving rise to pollution problems, market price typically does not reflect the full cost of production to the economy as a whole. Such goods are underpriced in the marketplace relative to other goods not producing pollution."

Because the air carriers have been able to get by without curbing noise, their costs of production are artificially understated. The industry's argument against compensating for noise costs is based on the assertion that the public benefits of air transport equal or exceed those costs and hence, by implication, that there need be no worry about the possibility that uneconomically large quantities of its services are being produced; indeed, the argument implies that failure to account for the enormous benefits has led to underdevelopment of the industry. But the argument treats individual gains and positive externalities indiscriminantly under the heading of benefits. 4 Consequently, the argument is fallacious, for the existence of individual benefits does not suggest an under-devotion of resources to the industry and cannot be offset against negative externalities in analyzing the

4 Altree, op. cit., p. 27.
issue of efficient resource use. Moreover, the industry argument from the fact that the industry creates benefits to the conclusion that it is not too large and probably not large enough is speculation biased by self-interest and it should not be accepted.

Pollution Control. In the past, environmental damage tended to be local in character and individuals or firms might escape at some reasonable cost. Moreover, the amount of pollution was so small that the recuperative powers of nature could repair much, if not all of the damage done to the environment. Today, the ability of ocean and atmosphere to accommodate wastes is being severely taxed, and the engineer's saying that the "solution to pollution is dilution" can no longer be made operative.

What has now become evident is that there is no way in the long run of avoiding the costs of using the environment. The policy question is not whether payment shall be made; it is when the payment shall be made, in what form, and how the costs are to be distributed.

The key to the control of environmental pollution involves changes in behavior ultimately based on changes in the values held by individuals. Behavior may be modified by use of subsidies, by the use of taxation, by the legal system in its
full range from proscriptions enforced by fines and prison terms to licensing and regulation, and finally by self-imposed rules of conduct initiated through a change in values. In the next section, these mechanisms for coping with environmental problems are studied.

Mechanisms for Coping with Environmental Problems

Since damage to the environment arises from many different sources and takes many different forms, proposed methods of coping with the problems also vary. In general, the economic approach seeks to transform the social costs of production and marketing to individual (private) costs, so that the price of every marketable product will reflect its full cost of production to the economy. Some of the major suggestions for achieving this objective fall into the following categories:

Setting Standards. The simplest way to deal with a pollution problem is to set standards for product performance and also for levels of harmful waste disposal which would reduce or eliminate the damages from the waste product. Along with the establishment of acceptable levels, a deadline for meeting these standards can be set. If a product does not meet the standard, then its production is illegal. For example, on April 30, 1971, the Federal Environmental Protection Agency announced national air quality standards covering six
common classes of pollutants: sulfur oxides, particulate matter, carbon monoxide, photo-chemical oxidants, hydrocarbons, and nitrogen oxides.

The setting of standards, without prescribing the precise device or machine to be used, would tend to promote individual initiative to find the least-cost solution for meeting the standard. On the other hand, there would appear to be no incentive to develop a device reducing pollution below levels of the standard. Moreover, this mechanism ignores the fact that some sources of pollution are more readily remedied than others. Robert Solow describes the problem this way: 5 "If two factories producing different commodities both contaminate the same stream to the same extent, it might seem natural to require each of them to reduce its contamination by, say, 50 percent. If that were done, it would be almost certain that the incremental cost of a small further reduction would be different for the two factories; after all, they use different production techniques. But then, it would be better if one of the factories -- the one with the smaller incremental cost -- were required to pollute still a little less, and the other permitted to pollute a little more. The

total amount of pollution would be the same, but the total cost of accomplishing the 50 percent reduction would be smaller. Since it is the total amount of pollution that matters, the cheaper possibilities of reduction should be exploited first."

Still another difficulty with standard setting is that it may be localized, in which case the environmental damage may simply be transferred to an adjacent area. A simple remedy for this problem is the development of a unified policy across political boundaries -- something not always simple to implement, however.

Subsidies. The introduction of pollution-control devices and techniques could be encouraged by subsidies from government to private firms and other governmental units. Subsidies may take a variety of forms:6

(1) Direct payment of all or part of the cost of control devices or systems.

(2) Reduction of taxes via tax credit, accelerated amortization, reduced assessment, etc.

(3) Direct loans at preferential interest rates, or the guarantee of loans for special purposes.

In general, the use of a subsidy is to facilitate purchase or installation of a specific pollution control technology. "But why", Solow asks, "should the government promote

6 Scherer, op. cit., p. 135.
the purchase of special equipment when other methods might be superior: the substitution of a cleaner fuel or other material for a dirtier one, or other changes in production methods, or the recirculation of cooling water, or the recovery of byproducts for further use, or even the relocation of production altogether.\(^7\) The simplicity of subsidies is compelling but this mechanism may be an expensive one way to reduce pollution if it limits the range of control techniques and especially if the alternative to waste treatment is the continued free dumping into the atmosphere or watercourse.

**Taxation or Imposition of Effluence Charges.** Firms or industries can be taxed according to the social costs they impose on society, assuming that the pollution damage caused by each firm or industry can be measured in some way. The tax might be levied in the form of an excise tax per unit of output or sales, or it could take the form of a charge on the amount and type of harmful effluence discharged by the firm into the air or waterway.

The objective would be a tax or effluence charge equal to the cost of the damage to the environment, so that the price of a product would reflect all of its costs of production.\(^8\) The higher price would decrease the amount of the product

\(^7\) Solow, *loc. cit.*

\(^8\) Scherer, *op. cit.*, p. 134.
demanded. A tax or effluence charge also acts as an incentive to firms to find methods of production which would produce less pollution damage in order to minimize their tax or effluence charge.

Among the mechanisms for coping with environmental pollution discussed economists tend to favor the use of effluent charges over available alternatives. One reason for this is suggested above. It is in the social interest that the cheapest method should be adopted to achieve any given reduction in pollution. "A system of taxes and charges," suggests Solow, "is more likely to accomplish this than direct regulation, given that we cannot possibly have all the desired facts." 9

This economizing on information is another reason suggested by Solow for favoring taxes over direct regulation. 10 The construction of a good schedule of taxes or fees requires information, but rather less than that demanded by alternative mechanisms.

Financial incentives are also generally easier to administer than direct regulation. By preserving decentralized decision-making, they induce everyone directly concerned to seek tradeoffs, substitutions, and improved techniques that might escape a central office. Additionally, a schedule in

9 Solow, op. cit., p. 500.
10 Ibid.
use is relatively easy to change if new information facilitating an improvement becomes available.

Moreover, according to Solow, taxes are generally preferable to subsidies on grounds of equity. "If some part of the population likes to do things or consume things whose production damages the national environment, it seems more fair that they should pay for the damage than that we should have to bribe them to stop."\(^{11}\)

The revenue from the tax or effluent charge could be used to construct facilities to reduce the damage to the environment by the particular industry or firm. In the Ruhr Valley, for example, effluence charges were successfully used to build facilities that upgraded the water quality of the river and that also served as an incentive for individual producers to modify their production methods to lower their charges. A number of other approaches to preventing the continued deterioration of the quality of the environment might be encouraged with the application of funds derived from effluent charges. For example, some part of the money could be used to set aside land for national prairies, national parks, national forests, national seashores and the like, and to maintain conditions for the survival of the animal and

\(^{11}\) Ibid.
plant life that has evolved with man over millions of years.

In practical political terms, a system of effluent charges on industrial pollutants is rapidly gaining favor as an approach to supplement government standards. President Nixon's Council on Environmental Quality has endorsed the idea. "Pollution charges," the CEQ said in its annual report, "would provide a strong abatement incentive and would tie environmental costs to the processes that generate pollution."¹²

Several pay-to-pollute bills are headed for Congress this fall.¹³ Senator William Proxmire, for example, plans to seek a national system of effluent charges to curb water pollution.

Environmentalists who once opposed effluence charges as a "license to pollute" now solidly back the idea. A coalition of seven groups including the Sierra Club and Environmental Action is urging effluent charges "to make the economic self-interest of polluters consistent with the goal of a clean environment."¹⁴


¹³ "Paying for Pollution by the Pound," Business Week, 4 September 1971, p. 78.

¹⁴ Ibid.
Present and Future Environmental Pollution Control

This chapter discusses three mechanisms for curbing pollution: setting and enforcing environmental standards, subsidies, and effluence charges. Ever since Congress passed the first control law, the government has sought to stem pollution by setting and enforcing environmental standards. But, there is considerable concern whether regulation presents the best course of action. No matter how stringent the laws, regulation is inevitably time-consuming and a cumbersome process. Not until the late 1970s, for example, will substantial aircraft noise pollution control become evident under Public Law 90-411. Consequently, economic incentives have won increasing support as a pollution-control weapon. Charges or taxes on the magnitude and intensity of noise are a lever that might spur the air transport industry to reduce its levels.

Affixing Responsibilities. As a point of departure for taking such action, the Report of the Study of Critical Environmental Problems recommends a principle of presumptive source responsibility: ¹⁵

¹⁵ "While remedial measures can be attempted on the routes along which they accumulate, we believe that these measures should be generally taken at the sources which we broadly define to include (1) sources or the points

in the process of production, distribution, and consumption, at which the pollutant is generated; for example, factories, powerplants, stockyards, bus lines; (2) protosources or earlier points that set the conditions leading to the emission of pollutants at a later stage; for example, the manufacturers of automobiles that emit pollutants when driven by motorists, or the brewers of beer sold in non-returnable cans that are tossed aside by the consumer; and (3) secondary sources or points along the routes where pollutants are concentrated before moving on to the reservoirs; for example, sewage treatment plants or solid waste disposal centers."

Points (1) and (2) are clearly identifiable sources of excessive aircraft noise. The first is the airlines who operate noisy aircraft and the second is the engine and airframe manufacturers who produce the aircraft.

The principle does not connote any element of blame or censure, nor does it foreclose a judgment concerning where the financial costs of correction should ultimately be borne. It does indicate a point of departure for analysis and action. It rests, in part, on the basis that, if something is wrong, it should be traced back to its origin and corrected in terms of its cause; in part, on a hypothesis that the source, protosource, or secondary source will typically be in the best position to take corrective measures, whether along or with help from others; and in part, on the view that the remedies
available, the criteria for choice among them, and the implication of remedial action can best be appraised at the sources as defined above.16

Accepting the Costs. Ideally, operators of older aircraft, which would often have very high abatement costs, could choose between investing in pollution control or paying the effluent fee — or some least-cost combination.

As long as the established standards were achieved, regulators could accommodate different levels of emission reductions from various sources of pollution. The result: high environmental quality at the lowest overall cost.

In reality, however, the financial costs ordinarily involved are likely to be large in relation to the scale of the source enterprise.

The Rohr report indicates, for example, that total investment requirements for acoustic retrofit of part of the existing jet fleet will range between $172 million and $792 million, depending on the configuration of the retrofit.17

16 Ibid.
If the source enterprise can neither absorb the cost nor pass it on, as will likely be the case for the air carriers, it is necessary to face a choice among failure of the enterprise, continuance of the pollution, or financial assistance out of public revenues.

The bill introduced by Senator Cranston of California would seem to be cognizant of this fact. The Cranston bill, S.1566, would require that by January, 1976, all subsonic transport aircraft operating in the United States reduce their takeoff, approach and sideline noise each by ten EPNdB from their 1971 noise levels, and authorizes appropriation of $35 million to the Administration of the FAA to undertake research to demonstrate that this can be done. A guarantee loan program of one billion dollars for financing made to air carriers for aircraft modification purposes is set up by this bill. Another form of assistance to air carriers is permitted under the bill by the statement that the "CAB shall not reject any increase in rates, fares, or charges filed by an air carrier if such carrier files with the tariff showing adequate proof that such increase is due to costs of complying (with the provisions of the Cranston bill)," either by retrofit or

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18 Senate Bill 1566. 92nd Congress, First Session, (19 April 1971).
early retirement of the aircraft.\textsuperscript{19}

In addition to these economic reasons for the government bearing some responsibility in achieving a solution to the aircraft noise problem there are other compelling reasons which derive from the conclusions presented in the next and final chapter.

\textsuperscript{19} Ibid., p. 5.
CHAPTER IX
A SYSTEMATIC APPROACH
TO THE ALLEVIATION OF AIRPORT NOISE

Introduction
The objective of this dissertation is to outline and define in some specifics a systematic approach to the alleviation of aircraft noise exposure. Pursuant to this objective, the conclusions of the proceeding inquiry are stated here, followed by recommendations derived from them for the organization and content of the approach. In addition, some implications for the future planning of the air transportation system are identified. The chapter begins with a discussion of the assumptions underlying the proposed approach to the flight noise problem.

Basis of the Proposed Approach
The development of a systematic approach to noise alleviation involves the full exploration of alternatives and their consequences. With the foregoing investigation of alternatives completed, the task remaining is to aggregate the total effort into a synthesis. The objective of the synthesis is to achieve a workable match between the flight industry fulfilling its transportation mission and reducing the intrusion
of unwanted flight noise. The problem is to outline and define a workable program to reduce community exposure to flight noise without putting the industry out of business.

The courses of action outlined here are premised on presently existing legal and institutional arrangements. Opportunities for guiding and influencing air transportation industry planning and decision-making are sought exclusively in the rule-making power of government agencies and their review and approval function over plans, methods and projects. Such an approach assumes that the current governmental-legal-industrial system is capable of solving the problem if it operates "correctly" and that it can be adjusted to operate in this manner through information, education, and other existing means. New laws, bureaus, programs, and priorities are all possible results of this approach. These courses of action do not reflect the different world that would prevail should the growing percentage of the population who have lost confidence in their ability to express themselves through existing structures gain command of the government's decision-making machinery.

Whether it is within the tolerance of the current governmental-industrial system to make the necessary adjustments is yet to be determined. However, one thing is certain, the present system of "muddling through" is not the solution. The present Boston airport situation is an excellent example. Local
citizen groups take pride in the fact that they have blocked the construction of the parallel 15-13 runway at Logan Airport. In the state house, the new runway has been made grist for the political mill, resulting in a roadblock of political opposition to the project. Due to its organizational biases and commitment to institutional survival, the semi-autonomous, para-governmental Massachusetts Port Authority has been extremely shortsighted, seemingly focusing attention on the transportation needs of a minority of the city's population while ignoring the interests of Logan Airport's neighbors directly affected by flight noise and other of the airport's adverse environmental effects. In fact, everyone involved has, with great adeptness, shown concern, and placed the blame elsewhere. The sad irony of this particular situation is the high probability that community exposure to flight noise could have been significantly reduced if the new runway had been constructed.

If the participants cannot achieve the workable balance sought, then the Federal Government must impose rationality from above. The Federal Government in turn must be capable of substituting a rational approach for its current "muddling through." The purpose of the following section is to outline and define in some specifics a noise alleviation program capable of satisfying this objective. As a rational
approach is framed in terms of the goals it is to serve, goals are the first topic of discussion.

Conclusions and Recommendations

From society's point of view, aircraft should be designed for quiet operation. All aircraft engines must be designed -- or redesigned -- to minimize noise exposure. Using the principles proposed by Robert Baron as a guide, a set of principles for aircraft noise abatement should be: 1

1. The noise from aircraft engines should be made compatible with the needs of the airport's neighbors, not the reverse.

2. Noise alleviation is to take precedence over industry-economic objectives.

3. Noise exposure is to be minimized.

4. Noise alleviation is to be recognized as a goal in planning and decision-making.

Once noise abatement is adopted as policy, the details of a systematic approach can fall into place. The first step in this direction is to develop the conclusions of the

preceeding inquiry and formulate from them a systematic approach.

The conclusions are:

. The noise impact on people, their communities, and civil aviation is large and costly and, barring unforeseen intervention, will be even more severe in the future.

. The most significant lack today is not technology but a focal point with sufficient authority and funds necessary to produce the comprehensive answer required.

. At the present time, the optimum approach to noise alleviation has not been defined. However, understanding of aircraft noise problems, solutions, and trade-offs, is sufficiently developed to indicate that a combination of the more effective measures discussed could save some millions of people in the United States from their current fate by cutting 20 PNdB or more from the noise levels they are now being subjected to.

. The most significant gains in noise alleviation are to be obtained at the source. Such methods of noise reduction at the source as re-equipment with quiet engines, operational procedures to minimize noise exposures, and the application of nacelle acoustic treatment technology are all known to be beneficial.
Either a VTOL or STOL air transportation system, by reducing the number of movements of CTOL aircraft, would reduce exposure to aircraft noise. Additionally, an increase in the quality of travel would be possible.

A VTOL system utilizing a quiet helicopter can operate from a near-city center location in a large densely-populated city at or below the existing ambient noise level. The operation of a quiet helicopter-VTOL system appears financially feasible.

Noise alleviation will involve high, short-run costs. In the short-run, the civilian air transportation industry can neither absorb these costs nor pass them on. Some form of loan or subsidy program enabling the industry to pay these costs in the short-run, and then recover them and pay them back over the long-run, is required.

Taxes or effluent charges are the most socially just economic devices for controlling pollution and also the most likely to be an effective incentive device in noise alleviation.

Organization. Existing Federal statutes, both explicitly and implicitly, express the need for a large portion of pollution abatement, control and enforcement to be conducted at state and local levels. The handling of many pollution
abatement matters at the local or state levels is a sensible approach, since the abatement facilities, such as sewage, solid waste disposal, and incinerator equipment are locally funded and operated.

While it is clear that the effects of aircraft noise are currently large and can be expected to increase, it does not necessarily follow that the Federal Government should be deeply and intimately involved in their alleviation. One can put the matter of aircraft noise into the category of being a local matter and allow the Federal Government to take an indirect interest. However, this inquiry has revealed compelling reasons for the Federal Government to be deeply involved in all aspects of aircraft noise. In brief, these are:

- There is no suitable market mechanism to correct the noise problem in the public interest.
- The nature of our free enterprise system is to encourage the market mechanism to supply the needs of the public.
- In special cases, where the market is not operating properly, or in the public interest, the government may need to intervene to secure the results which are desired. In the case of aircraft noise, there is no suitable market mechanism which can be expected to respond promptly and effectively to the harmful effects of
aircraft noise on people and their communities; that is, no one is directly in the business of buying quietness.

Effective remedies for preventing environmental degradation lie at the national level.

Airport planning proceeds on a local and regional basis, and the burden of land-taking and environmental disruption falls principally upon the city. Because environmental costs are borne locally, no effort has been made to eradicate them through technological improvements on a national scale of which the national system is capable. It does not seem possible to solve local airport planning, construction and management problems independently of a Federal plan for development of the national air transportation system.

No present effort will solve the aircraft noise problem. Even though today's concern for environmental effects has called forth, for the time being, some coordinated interest on the part of local, state, and federal officials, this cannot properly serve as a substitute for a rational, coordinated effort to develop a national air transportation system that efficiently serves the needs of the nation without disrupting the environment of millions of people.
The government is broadly involved in setting environmental-pollution standards.

Aircraft noise is but one aspect of the much more general problem of environmental protection. Since there is considerable Federal Government concern, coupled with programs to set standards and make regulations, an attack on aircraft noise is only part of a more general Federal policy.

The Federal Government is broadly involved in aviation affairs.

In its role of protecting the public, the government certifies aircraft for airworthiness. Since certification of aircraft involves both structure and flight capability (e.g., power and flap settings), it inherently involves the noise that an aircraft will produce in various flight configurations.

Government participates in airport location and development. In the past, under the Federal Aid to Airports Act and in the future under the Airport and Airways Development Act, the Federal Government, recognizing its responsibility to promote a safe and efficient air transportation system, has had a voice and had contributed funds to the selection, development and modification of airports by type and location. This
responsibility of the government, regarding airports has not changed but has been reinforced by creation of the Department of Transportation to effectively meet the challenge of achieving a balanced transportation system.

Government establishes flight paths. Airport runway use and the terminal area approach and departure paths are most important in determining what parts of the urban area will be exposed to noise. All of these are established by the FAA.

Today there is no instrument of government on any level capable of fulfilling a comprehensive noise abatement function. Many suggest the ultimate answer may be a Department of Ecology. But this remains to be developed after the new ecology is more clearly defined.

For the immediate future, transfer of authority for noise alleviation from the Federal Aviation Administration to the Environmental Protection Agency is a practical answer. The Federal stature of the EPA and the Agency's expertise are suited to the task of establishing and enforcing aircraft and aviation engine noise programs. Political sentiment to keep noise control authority within the FAA is strong.² It is

most unclear what gain is thought to be had by maintaining the status quo in this regard. The FAA is subject to all the problems which infect present administrative agencies, with the advantage of only limited inside perspective: it may have become a captive of the industry it was to oversee. The very specialization of the FAA, means that the agency is likely to bring a particular perspective to bear on environmental problems caused by flight noise.

A clause of the Clean Air Act of 1970 (P.L. 91-604), establishes an Office of Noise Abatement and Control in the Environmental Protection Administration. Legislation is now being considered that would authorize the EPA to regulate noise from several sources, including transportation. The need is for a public institution that can and will translate public concern with flight noise into effective governmental action. For this task, the EPA is uniquely qualified.

**Elements.** A noise alleviation program responsive to the concerns of the airports' neighbors will be a radical departure from present circumstances. It will require fundamental research as well as engineering and development programs.

At the present time, only the beginnings of a systematic noise alleviation effort can be identified. As a minimum, this inquiry suggests it include:
. Implementation of noise reduction at the source through fleet re-equipment with quiet engines and nacelle acoustic treatment. Aircraft should be a minimum of 20 PNdB quieter than those operating today.

. Development of flight paths and procedures which make an optimum trade-off between noise impact and safe, efficient flight.

. Application of economic mechanisms to stimulate prompt and effective implementation of measures to reduce aircraft noise at the source -- including the rapid retirement of noisy aircraft in the current jet fleet and their replacement with aircraft of a minimum of 20 PNdB quieter than those operating today.

. Creation of a source of funds for programs such as those cited above. Passage of the Cranston Bill would be a positive first step in this direction, but a more comprehensive source of funds will be needed. Since money in the Aviation Trust Fund is set aside for the future development of aviation and noise is the most significant factor thwarting the future development of aviation, it is logical to apply trust fund money to noise alleviation efforts.
Organization and implementation of a program to develop rotary wing, short-haul air transportation system: a program capable of surmounting or by-passing the administrative impasse currently preventing system development.

If in the event that aircraft engines cannot or will not be designed to operate quietly for another five years or more, the number of intrusions must be restricted. The NEF methodology indicates that the annoyance from aircraft noise is the result of a combination of the amount of noise and the number of exposures. The number of flights, especially in the critical early morning and evening hours, must be curtailed.

Implications for Air Transportation System Planning

This dissertation has explored the problem of aircraft noise with the objective of defining a systematic approach to its alleviation. If it is possible to point to a single central consideration that has been evident in this inquiry, it is the complexity and variety of factors that bear upon the problem and affect its alleviation. In closing, however, it is important to look beyond an adequate solution to the aircraft noise problem and focus upon the planning process that is to guide the future design of the air transportation system.

The words, "...to guide the future design of the air transportation system," to echo a notable statement of former
Northeast Corridor Transportation Project Director, Henry Bruck, require emphasis. It is difficult," Bruck has said, "to apply the term 'system' as a description of the existing collection of facilities and vehicles. It is even more difficult to credit this collection with being the product of a fully rational planning process. Existing air transportation services are largely the result of discrete, isolated decisions. Anamalously, these decisions have both supplied needed services and have caused serious environmental conditions to develop."

The suggestions of the previous section seek a solution to the immediate problem of aircraft noise. Over the long-run, sensitivity and responsiveness to environmental requirements in all future airport and aviation development will be needed. This implies actions of many kinds must be taken.

First of all, the planning process for air transportation facilities and services must involve a comprehensive analysis of all the costs and benefits involved. The environmental costs are not an insignificant component of this analysis. For example, in planning a major new airport that may cost upwards of half a billion dollars by the time it is fully operational, it is inconceivable that an environmental study involving a few tens of thousands of dollars, hurriedly contracted for a few months before the final decisions are made would be adequate. The National Academy of Sciences' study of the proposed runway expansion at Kennedy Airport occupied the full-time attention of several dozen researchers for one month and cost in excess of a third of a million dollars. The Academy study is an example of the kind of study any major airport expansion should receive, but started long before decisions are made and spread over a longer period of time.

Secondly, the expansion of air transportation facilities can only be done rationally as part of a national transportation policy on the one hand, and a comprehensive land use plan for the region on the other. The latter requirement is a mandate of the Intergovernmental Cooperation Act of 1968.

At present, the former is not possible, inasmuch as there exists no operative national transportation policy. Interim guidelines are provided by regional land use and
transportation plans. But this is not satisfactory in the long-run and efforts must be made to force Federal agencies to prepare comprehensive national guidelines.

A systematic approach to aircraft noise alleviation has been outlined and defined in this chapter. Ideally, noise alleviation would be but one part of a much more comprehensive transportation planning effort.

Third, the public with its multi-faceted environmental concerns, must be admitted much more fully to the planning process than it has been in the past. Incorporating meaningful citizen participation in the planning process is never easy. Planning is a relatively continuous process, with decisions made frequently and often imperceptively. But while citizen participation is not feasible at every point, there usually are landmarks in the decision-making process at which citizens' participation can be invited. Of course, if this participation is to be meaningful, agencies will have to operate openly and make their information sources and planning studies readily available.

One final comment. The future growth of airports and particularly the development of a short-haul air transportation system are critically dependent on improving the compatibility between airports and communities, with respect to noise
and other environmental variables. Without some form of action, mounting citizen opposition is inevitable. Implementing a systematic program of noise alleviation will help. So will including environmental considerations and citizen inputs in an effective and meaningful manner during the planning phase. But foremost, there must be a fundamental reorientation of the industry's philosophy. Emphasis can no longer be concentrated on what air transportation can do for people. Instead, what the industry does to people must receive equal attention. Without this, future growth of the industry is doubtful.
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