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EXAMINATION OF SELECTED ALTERNATIVE MEANS OF ACHIEVING SIGNIFICANT AIRCRAFT/AIRPORT NOISE REDUCTION

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May 15, 1973

for

THE GEORGE WASHINGTON UNIVERSITY

Program of Policy Studies in Science and Technology

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INTRODUCTION

This report, the product of thirteen man/days of research of currently available documentation, analysis and preparation, proposes to produce most of the answers to most of the same questions toward which the Department of Transportation's Office of Noise Abatement has been addressing many, many times the same amount of manpower and hundreds of thousands of dollars over the past four years. It is recognized that some of the data herein have been derived as a result of that effort; however, it must concomitantly be realized by the reader that a good portion of the aforecited effort is not yet complete. Therefore what follows is the writer's best assessment of the values, shortcomings, costs, time-framing and feasibility of the aircraft noise abatement and prevention alternatives examined. This is particularly true in the section of the report dealing with recommended combinations of selected strategies.

I. SUMMARY

A. General

The report examines various individual means of achieving significant aircraft/airport noise reduction and/or prevention, their costs in dollars and other terms, their technical and operational feasibility, and the time frame during which each may be accomplished. Additionally, a selective detailed examination is made of certain recommended means, and their cumulative effects on the reduction of noise.

The means, noise reduction attainable, social and other costs, assessment of feasibility, and time frames for accomplishment are delineated in a series of figures attached to this paper.

Figure 1 delineates the factors used in evaluating each of the strategies chosen and the results of the examination. It considers the following denominators for the strategy, taken alone rather than in combination with other alternatives:

1. Means -- this is a description of the strategy.
2. Credits -- what reduction in NEF 30 & 40 contour areas (using the 1985 base area as the 100% model), the number of people affected favorably by the reduction, and/or what other less tangible benefits may be derived from application of the alternative?
3. Debits -- what are the dollar (and other) costs of implementation of the technique and the limitations which may be expected therewith?

4. Segment Affected by Costs -- who pays for the change? What alternative means of financing are suggested? (Shown parenthetically)

5. Status -- When, in gross terms, can we expect to see the results of the change?

6. Implementation Time Frame -- specifically what years are involved in the implementation process?

7. Feasibility Index -- what is the degree of practicability in implementing the technique as a sole choice?

8. Legal/Institutional Status -- who must take action in advance of implementation?

9. Data Source, and 10. Remarks -- self-explanatory.

Time available precludes a detailed examination of all of the strategies for achieving relief in NEF 30/40 impact areas. They were each screened for their obvious noise-reduction benefits; only those procedural steps, technological changes, or other efforts which promise some reasonable degree of noise abatement in critical areas are examined beyond that point to determine their costs and benefits and their feasibility from other aspects.

Because of the paucity of technical data available in regard to noise reduction involving business jet aircraft, as well as the obvious preponderance of the problem being engendered by the air carrier fleet, no specific references are included herein relative to the former. Obviously, certain have uniform applicability, and to that extent the entire fleet was considered.

B. Conclusions and Recommendations

1. The cost/benefit relationship of all source abatement strategies except engine nacelle acoustical lining does not justify their further consideration in the near term. However, continued and intensified effort is needed to insure that new airplanes entering the fleet, and especially their engines, are designed and/or treated to the maximum practicable extent toward the reduction of noise.

2. Engine nacelle acoustical lining produces a significant reduction in source noise at a not unreasonable cost, provided that this cost may be shared by the public along with the user.

<u>It is therefore recommended that</u> a program be instituted without delay to require the acoustical treatment of JT3D and JT8D engine nacelles as delineated in the various references herein.

3. The sound-reduction values achievable by nacelle treatment can be increased significantly by combining that approach with the early implementation of certain operational procedures.

4. There is no difference between the reduction values achieved by two-segment approaches and higher glide slope angles. NO

5. The small gains apparent from the use of two segment approaches, as opposed to the election of the use of a higher transition altitude, do not justify the airborne and ground installation costs involved. NO

6. Because of the diversity of size, shape and location

of problem areas among the various noise-impacted airports, it may be more practicable at some locations to adjust the glide slope angle upward, utilizing a higher transition altitude in association therewith, and at others to rely solely on the latter operational procedure.

<u>It is therefore recommended that</u>, as appropriate to each airport concerned, the operational procedure/s discussed in 6. <u>supra</u> be instituted at an early date.

7. As a result of the foregoing, the present NEF 40 contour areas will be markedly reduced in size and, therefore, population.

<u>It is recommended that</u> land use strategy a., relocation of persons within NEF 40 contour areas, be instituted as soon as a firm determination can be made regarding the extent of the <u>remaining</u> impact area.

<u>It is further recommended that</u> costs involved in accomplishment of this recommendation be borne in considerable part by the public at large.

8. Zoning of undeveloped land for noise-compatible use is an essential strategy in the prevention of damage to the public health and welfare.

<u>It is recommended that</u> necessary legislation be enacted which will ensure that this action is taken in respect to new as well as existing airports.

9. Withholding of ADAP funds in the absence of adequate land use planning will force airport and land use control authorities to take appropriate steps to prevent loss of funds.

<u>It is recommended that</u> rulemaking be promulgated

by the Federal Aviation Administration which will direct the withholding of ADAP funds in the demonstrated absence of land use planning in respect to noise.

10. Curfews per se are unduly restrictive and often costly. However, curfews intelligently and selectively applied may be utilized to achieve beneficial results without undue expense.

It is therefore recommended that action be taken on the Federal level (so as to ensure standardization of application) to institute, as of a reasonable effective date subsequent to the inception of the recommended engine nacelle retrofit program, a curfew on all flight operations in terminal areas between the hours of 10:00 P.M. and 7:00 A.M. local time, except for those aircraft whose engines (a) meet FAR 36 certification noise emission standards, or (b) have undergone nacelle acoustical treatment.

II. DISCUSSION

A. General

The basis for selection of the various means of achieving effective noise reduction has been discussed earlier in this report and does not bear repeating. The parameters evaluated in considering each of the sub-strategies were researched in the most current literature available. The values quoted are derived, in part, directly from these sources; in some cases limited extrapolation (on the order of a ratio of 3:4) was accomplished in order that each datum would be relative to the next.

The various means, techniques, procedures (or choose your own word) for achieving significant reduction of noise on and in the environs of airports were organized into four of what I have chosen to call strategies. These are entitled:

1. Source Abatement
2. Operational Procedures
3. Land Use
4. Service Restriction

No significance should be read into the order in which the above listing appears, nor to the rank order in which each sub-strategy is delineated. Each of the means has been evaluated individually, as if it were the only one being considered. The results of this evaluation are displayed in Figure 1.

It should be borne in mind that the costs of a total system (involving elements from most, if not all, of the strategies discussed herein) cannot be computed by simply summing the individual costs of each of the alternatives selected. This is because the improvements achievable through the application of service restriction, source abatement and/or operational procedure strategies lessen the numbers of people, acres, square miles, households, or whatever denominator, to be dealt with by land use options.

Because of this interrelationship before evolving a final choice of means it was necessary to inspect various combinations in order to assess the effect on the selections, if any, of number of flight operations. For this purpose, air carrier airports were grouped into three categories by number of annual operations (predominantly air carrier), with the break points as follows:

1. 6000 - 75000
2. 75000 - 200000
3. 200000 - 675000

This distribution represents 103, 21, and 13 airports, respectively, in each of the categories.

It was found that (as might readily be expected) that the number of operations did not affect the source abatement technique applied. This variable made its effect felt on the viability of various operational procedures and land use strategies. However, other factors also affected choices in these strategic areas so that the net result was found to be the lack of need for subcategorizing final selections of recommended noise abatement techniques by level of airport activity.

This report concludes, then, with a brief discussion of each of the means recommended for implementation and the cumulative costs and effects of the total selection.

B. The Abscissa of Figure 1.

The factors considered in respect to the strategies evaluated are defined herein in order that the reader may be fully apprised of the extent (or the lack thereof) of coverage of each.

1. Credits

This term is used to describe the benefits derivable in terms of reduction of land area within NEF 30[1] and 40[2] contours, the estimated number of persons affected favorably by this reduction[3] and/or other tangible or intangible benefits obtainable as a result of the application of a specific noise abatement or prevention scheme.[4]

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1 - 4 Items labeled A, B, C & D under "Credit" column in Table 1.

2. Debits

This term is used to describe 1972 dollar costs (where determinable from reference material) as well as qualitative statements concerning major limitations involved the implementation of the means under discussion. In calculating the costs of refitting aircraft with new engines, the development and certification costs, estimated by various sources to be in the order of $500 million, were not singled out. This figure represents a sizeable sum required to be advanced by the engine and airframe manufacturers, but is presumed to be recovered in their charges to the air carriers and is thus depicted in the capital costs attributed to the latter for this option. Details concerning the specific increases in airline operating costs as a result of supporting the additional capital outlay required to finance <u>any</u> source abatement strategy have been left to the devices of the experts in the fiscal aspects of airline management.

3. Segment Affected by Costs

This subject area delineates the government entity, agency or user group most likely to be saddled with the burden of financing the costs of the strategy. Where there is a parenthetical entry in this column on Table 1, it is intended that consideration be given to the alternative cost recovery means described therein. These alternatives are discussed at greater length in the examination of each of the strategies which follows in this report.

4. Status

This heading is used to describe in general terms the effective period of the application of the atrategy being examined. Its values are: presently employed, near future application or effect, and for future application or effect. These values are further refined under the next topic.

5. Implementation Time Frame

This subject is treated both generically and chronologically. The definitions of the previously described terms (subparagraph B. 4. infra) are roughly as follows:

Present - Now until the end of CY 1974

Near Future - Mid-1974 to the end of 1978

Far Future - Beginning of 1978 to 1985

6. Feasibility Index

This is a subjective evaluation of the overall practicability of the sub-strategy under examination, considering its cost in respect to the benefits to be derived, the time period in which it could become effective, the difficulties anticipated in effecting the program, etc. It is intended that the feasibility index represent what a large body of reasonable, informed people would consider to be the relative worth of each of the means, using the terms "Practicable", "Marginally practicable", and "Impracticable".

7. Legal/Institutional Status

The application of this term in the report may have a somewhat different significance from that being employed by others involved in this effort. Its use herein is intended to convey the need (or lack of need) for regulatory, legislative, and/or financial planning action on the part of the Federal Government, State or local legislative or regulatory authorities, operating agencies or the aviation industry, as indicated.

C. The Ordinate

Before proceeding with a discussion of the strategies which may be employed to combat the problem toward which we are seeking recommended solutions, the following assumption must be enunciated. In order to conserve time and effort, as well as expense, it has been assumed that the reader is basically familiar with the various types of source modification techniques, operational procedure and land use strategies hereinafter discussed. Where the writer has doubts about the validity of this assumption, he has provided explanatory text material.

1. Source Abatement Strategies

These strategies represent various degrees of severity in terms of coverage as well as cost. Much of the body of reference material on this subject goes into greater detail in the breakout of options and combinations thereof. To do so here would be wasteful of the reader's time, since a specific list of references is provided.

All of the percentages of reduction delineated are based on the 1985 base case area equalling 100% and the population data base is the same year, unless otherwise indicated.

As further explanation of the foregoing, it has been projected in Reference 2 that normal fleet attrition and replacement with aircraft equipped with quieter engines will produce by 1985 a reduction in the NEF 30 impact area to a value of 70% of the 1972 area. This new base area (1985) is used as the 100% model against which the effects of each of the following strategies is plotted.

The Department of Transportation has indicated that 90% of the noise impact areas are created by operations at 23 airports. Population data were available for the NEF 30 contours of 17 of these airport environs. Those six locations for which data were not available were found to be roughly representative of the remainder; therefore, the foregoing population data were extrapolated, first on a 4:3 basis to arrive at a 90% NEF 30 population figure, then on a 1.11:1 to derive a 100% population exposure. The resultant NEF 30 figure was 6,182,788 people. It had been previously observed by the writer that there appears to be a ratio of about 10:1 between NEF 30 and NEF 40 areas: thus an arbitrary

10% of the foregoing population value was assigned to the NEF 40 areas. It should be mentioned again that this population figure is that expected to be exposed in 1985 if nothing is done in the way of noise abatement except rely on attrition and replacement of the airline fleet.

a. Replace Fan - JT3D Engine

This technique, applied to that portion of the U.S. airline fleet (B-707 & DC-8) forecasted to be extant in 1978, would reduce the area within the NEF 30 contour by 40% in the case of takeoffs and 67% for landings. This would affect 2.473 to 4.142 million persons favorably. The comparable values for the NEF 40 contour are 61% for takeoffs and 96% for landings, affecting 377,000 to 593,000 people.

Best current estimates of the capital cost of this strategy are about $720 million. One penalty associated with the new fan would be a 3% increase in the gross weight of the aircraft. On the basis of the current policy of the Administration, as enunciated by the Department of Transportation the costs for this modification, as for all source abatement strategies, will be borne by the users of the airspace. An alternative to this policy, that is, a partial Federal grant, is discussed in the next section of this report.

The effect of this modification could start to be felt by mid-to late 1974, and the program could be completed by early 1977.

Because of the costs involved it is considered only marginally practicable, and would require action on the part of the Federal Government to initiate the requirement for the change and on industry to effect it. (Ref. 1 & 2)

b. Replace Fan - JT3D & JT8D Engines

This strategy would affect the entire fleet of aircraft presently equipped with low bypass ratio fan (LBPF) engines, at a cost of $2,100 million, and would produce an increase in benefits (compared to the preceding means) of 1-2% reduction in the NEF 40 area. It would provide relief to an additional 123,000 people in NEF 30 areas and 18,600 in NEF 40 areas.

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In addition to the costs involved, this change would cause a 7% loss in range for the B-737 727 and DC-9 as well as a 4% increase in specific fuel consumption for the latter aircraft. Because of the considerably larger number of aircraft involved, it is anticipated that this program could not be completed until the end of 1979, at the cost value shown. It would require the same type of regulatory and industry action as heretofore described for JT3D engines alone, and which is required for the application of all of the source abatement strategies.

On the basis of the very small increase in benefits accruable from this strategy as opposed to its costs, it is deemed impracticable. (Ref. 2)

c. Replace JT3D Engine - equipped Aircraft (B-707 & DC-8)

This strategy proposes to scrap (or sell for use outside the United States) all of the projected remainder of the four LPBF engine equipped aircraft and replace them with DC-10, L-1011 and B-747 airplanes. The benefits derivable from this maneuver are essentially the same as for b. above, but the costs escalate to $5,534.4 million. This projects an additional requirement for 76 B-747s and 164 DC-10/L-1011 aircraft to compensate for the passenger/cargo capacity of the replaced B-707 and DC-8 aircraft, over and above the projected increase in the wide-body jet transport population.

Production of sufficient additional aircraft to meet the demands of the application of this strategy could not commence before 1976 and would not be completed until 1980, thereby implying an airlift shortage between 1978 and 1980 (presuming that there was a forced retirement of JT3D-engine aircraft by that time) or extension of in-service time of "noisy" aircraft until replacements therefor came off the production line.

On the basis of all of the foregoing this strategy is deemed to be impracticable. (Ref. 1 & 2)

d. Reequip All Current Aircraft with "Quiet Engines"

The potential benefits to be accrued from this strategy are markedly greater than all others in this realm. It has been opined that 94-97% of the poeple in NEF 30 areas and 98-99% of the NEF 40-affected persons (5.8 - 5.9 million and 600-606 thousand, respectively) would be relieved by this change. Its costs (apart from the previously mentioned $500 million development and certification outlays) is about $7,240 million. Because of the lead time involved in the development and certification processes, the first of the production engines can not be expected to be installed on an aircraft until early 1978, and the program could not reasonably be expected to end before mid-1981 at the earliest.

Principally because of the dollar cost, but additionally because of the alternatives available through a combination of strategies, it is deemed impracticable to pursue this course for the near term. However, continued and intensified effort is called for to insure that new airplanes entering the fleet, and especially their engines, are designed and/or treated to the maximum extent practicable toward the reduction of noise. (Ref. 1 & 2)

e. Engine Nacelle Accoustical Lining

This strategy, applied to all LPBF engines, would reduce NEF 30 areas by 36% for takeoffs, 62.4% for landings; the corresponding reductions for NEF 40 areas are 57 and 94.5%. The ranges of population affected are 2.225 to 3.858 million and 352,000 to 584,000, respectively. Its costs are variously computed as $475 million (Reference 2) and $396 million (Reference 3) although there may be some variation in the number of aircraft upon which the latter figure is based. Another cost is the imposition of an additional 2% onto the direct operating costs of the aircraft.

This program could commence by mid-1974 and would be completed, at a "moderate" schedule, by the end of 1978. A "fast" schedule would involve considerable overtime pay costs, but could advance the completion date to the end of 1976.

When considered in context with some of the material which follows in this report, and even when viewed alone, this means is considered to be practicable.

2. Operational Procedures Strategies

a. Steeper Glide Slope

This procedure, which calls for a glide slope angle of about 3.5°, as opposed to the present maximum angle of 3.0°, would provide relief as follows: NEF 30 - 25-76%; NEF 40 - negligible. Affected by relief: 1.547 to 4.7 million people.

The above-cited relief has some concomitant costs. These are in the order of $15-20 million, for recommissioning, phototheodolite-measured flight checks of the glide slope at the new angle. This cost would be one attributed to the FAA, since that agency has the responsibility for performing such checks.

Other potential limitations to the application of this means of noise abatement are the problems attendant with gaining acceptance from the pilot community of this procedure, which increases vertical velocity by one-sixth to a value, in the case of a ground speed of 150 knots on final approach, of 927 feet per minute. This sink rate borders on, if not exceeds, what is considered to be the maximum practical rate consistent with safety in the approach zone. In instrument meteorological conditions, with poor visual reference for touchdown, this rate of sink could cause some problems in aircraft control at the touchdown point.

Subsequent to obtaining concurrence from all segments of the user population, (required in advance of a radical change in navigation aid alignment) the time frame for implementation of this strategy would range from its beginning in mid-1974 to completion by mid-1976. This time span is almost inexorable because of the limitations on airborne flight check equipment, aircraft and trained personnel. The feasibility index attributed to this procedure is: marginally practicable. (Ref. 5)

b. Higher Transition Altitude to Final Approach

This procedure's application would reduce NEF 30 contours by about 40%, but would have no effect on the NEF 40 area. As a result of the reduction in NEF 30 contour size, 2.437 million people would no longer be exposed to the amount of noise associated with this value.

Its costs are somewhat nebulous in that they are caused by delays as a result of reduced runway acceptance rate created by a considerably longer common final approach course. I have estimated them to be in the order of $10-20 million annually, reflected in increased direct operating costs of the users of the airspace. This figure reflects the extra aircraft operating time, concurrent fuel consumption and attendant labor costs incurred as a result of the delays to air traffic created by the application of this procedure universally. No computation has been made of the considerable costs of air traffic delays to the persons most directly affected, the passengers involved, but they would be considerable in value of time and in inconvenience.

However, on the other side of the coin, this means does have application without significant penalty at locations of lower traffic density wherein delays are not a factor. The strategy could be applied immediately in some areas, and in the near future in others, pending a review and revision, as necessary, of terminal area airspace procedures.

The benefits derivable from the application of this procedure are incorporated in the two-segment approach strategy, which is discussed immediately hereafter. It is considered that this procedure is practicable with the qualifications which have been delineated. (Ref. 4)

c. Two-segment Approach, 3-mile Transition

This means of lowering perceived noise levels caused by landing aircraft embodies an initial descent angle of 6°, and a transition therefrom to a "standard" 3° glide slope at a point about 3 nautical miles from touchdown, when the aircraft is at an altitude of about 1,000 feet above airport elevation. It includes a considerably higher initial transition altitude than the 1500-2000 feet above airport elevation associated with current procedures utilizing the ILS.

Airborne requirements include installation of a computer which would generate the 6° glide slope and cause data regarding the aircraft's position relative thereto to be fed to the flight director and the approach coupler, both of which instruments would require some modification to accept this additional input.

An additional ground-based requirement is a DME (Distance Measuring Equipment) installation co-located with the glide slope transmitter for the ILS. Data from the DME and the aircraft's barometric altimeter would be fed to the new computer, from which bases the 6° glide slope would be constructed.

Relief to be anticipated from the application of this technology exists only in the NEF 30 contour area, which would be reduced from 25% to 76%, depending on the airports chosen for implementation. The resultant population figure relieved from NEF 30 noise exposure would range from 1.85 to 4.7 million people.

Costs of the system are calculated to be $20 thousand per aircraft installation for a basic non-redundant system, equating to $50.1 million for a 2505-plane fleet (1976 projection). Beyond that point in time it is assumed that necessary airborne computations could be performed by existing computers installed in aircraft delivered to the fleet.

The ground-based portion costs are $50 thousand per installation (in place and operating) and, based on a total system installation, represent a capital cost of $70.15 million for current ILS installations not presently equipped with DME, or $24.5 million, based on the FAA's projection of 490 systems extant by the end of 1976.

This strategy is presently undergoing a joint flight evaluation by FAA, NASA and United Air Lines at Los Angeles International Airport. Results of this activity will be used to develop standards for redundant airborne installations, etc. In addition, two other airlines, National and Pacific Southwest Airlines (PSA) are assessing the procedure in visual meteorological conditions.

On the basis of the data at hand, this means of abating aircraft noise is deemed practicable. (Ref 1, 2, 5, 9)

d. Thrust Reduction on Climbout -- Reduced Flaps

The effects of application of this strategy are derived principally from other than JT3D-equipped aircraft because of their normally greater ratio of power to spare, although a lightly loaded B-707 or DC-8 can also create noise reduction benefits with a power reduction after takeoff, if safety conditions permit. Across-the-board gains through use of this technique are from 14-54% reductions in the NEF 30 and 40 contours, the values varying inversely with distance from the airport. Population exposure reductions are in the range of .865 to 3.34 million for NEF 30 and about 10% of these values for NEF 40.

There are no dollar costs associated with this technique, already in use at many noise-impacted airports. This strategy is deemed to be practicable for application as required. (Ref. 7, 8)

e. Use of Preferential Runways

This technique has been applied at a number of high density airports with adequate configurations and runway lengths, and the varying character of whose environs offers an opportunity to direct landings and, principally, takeoffs over land areas which are less noise-critical. Directed use of a preferential runway is usually predicated on a maximum crosswind component of 15 knots.

There are no measurable gains associated with implementation of this strategy, since most, if not all, of the published NEF contours in existence today are predicated on the use of this system. This report could not be considered complete, however, without mentioning this means and, additionally, it ties directly into the next strategy to be discussed. It goes without saying that this technique is feasible.

f. Dispersed Parallel Runway System

At J. F. Kennedy Airport, New York, one of the airports of highest traffic density at which preferential runway systems are utilized, the noise burden throughout the periphery of the airport complex, and particularly under the airport complex, and particularly under the flight paths of departing aircraft which were complying with prescribed noise abatement departure procedures, that an attempt has made to "spread the load" in an effort to achieve some measure of reduction of complaints.

The system presently under evaluation is one whereby the noise impact under a given route is calculated cumulatively by number and type of departing aircraft. When a predetermined exposure level has been reached, and operational conditions permit, the flow of traffic is changed so as to direct it over a different area, again until that area has reached its predetermined noise impact level, etc.

The total noise impact over the long term is the same for each of the areas as would be encountered by random distribution of runway usage under the former preferential runway system. However, it has been postulated that less prolonged periods of exposure will serve to lower the complaint level which, although not an accurate measure of noise impact by any means, is an indicator of the effects under discussion herein, particularly in the New York area. Preliminary indications appear to be validating the hypothesis, although what changes may arise as warmer weather, with more open windows, arrives remains yet to be seen.

There are some costs attributable to this program, incurred by the FAA in personnel costs required to monitor the program and by the users in delays encountered during traffic switching periods. Were the program to be instituted at all of the high-density terminals at which it has applicability, the personnel cost would approach $750 thousand annually.

This strategy has no tangible effect on actual noise reduction. Notwithstanding this, as an interim measure which may provide some psychological relief during the time frame that other, alleviating, programs are being implemented, it is deemed to be practicable.

g. Increased Climb Gradient -- No Thrust Reduction

This procedure, which has undergone empirical analysis and some flight testing directed toward obtaining subjective reactions of passengers and flight crewmembers by at least one major airline, is capable of producing some reduction of noise in excess of that generated by the "standard" climb gradient, to a marked degree for close-in communities. Specific numbers are not presently available. The utilization of this procedure at high traffic density airports has drawbacks in that the differing climb rates of, for example, a heavily loaded B-707 and a lightly loaded B-727 would require that the airspace and control actions be tailored to the capabilities of the former while accommodating the latter. This type of flexibility, although eminently desirable in the ATC system, does not exist, nor is it forecast to exist for some time to come. Howevar, by applying this strategy selectively (as is true of most, if not all, of the operational procedures) some benefit may be obtained in noise reduction at certain airports, with no dollar costs being incurred by anyone. It is therefore considered to be practicable, as qualified herein.

3. Land Use Strategies

This is the most difficult of the strategies to assess because of the multitude of problems associated with each of the potential alternatives. However, there may be an advantage in having a "non-expert" look at some of the choices, in that there exists the possibility that he may be able to see the forest rather than just the trees.

Although there are some sub-variations in the application of the techniques under this major heading, again time and particularly lack of expertise precluded detailed examination of each of them. What follows is a gross description and discussion of the major means available or potentially available.

a. Relocation of Persons Within NEF 40 Contour

This means of reducing the impact of airport/aircraft noise impact may be characterized in medical terms as radical surgery. That is not necessarily to say that it is not good, practicable, or feasible, but rather that it represents a serious disruption in urban society. Its various pros and cons are more than adequately discussed in a wealth of study documents prepared as a result of extensive investigation into its many effects. In the considered judgment of this writer, its total effect, unmitigated by any other influence, would be felt by 618,000 people. Its gross dollar costs would appear to be in the neighborhood of $5,580 million.

It is rather obvious that an undertaking of this magnitude is far beyond the fiscal capability of local, or even State, interests to perform, and that some forms of Federal assistance would be an absolute requirement. This would include personnel, management and pecuniary assistance in the form of a grant. This suggestion runs counter to the previously enunciated position of the Federal government that the costs involved in noise abatement shall be borne by the user. A few words expressing the opinion of the writer are in order at this point. They are directed to the subject of grants for technological improvements in the engines of the "offenders" as well as to the application of this philosophy to land use strategies.

There is a charge made in the Noise Control Act of 1972 that certain actions shall be taken "in order to afford present and future relief to the public health and welfare from aircraft noise..." and another excerpt, "...which emits noise capable of adversely affecting the public health or welfare..." However, in Section 3 of this legislation, entitled "Definitions", there is a noteworthy absence of <u>any</u> reference to the terms "public health" and "welfare". It can only be presumed that this omission was by design and not by accident, thus leaving the definition of these terms, as that of beauty, in the eye (and in this case, ear) and mind of the beholder.

That apparently being the case, I choose to propound that the public at large bears some goodly share of the responsibility for its own health and welfare as in the case of aid to dependent children, old age assistance, welfare payments to the indigent, and so forth ad infinitum. Certainly those who chose to locate themselves in such proximity to a source of noise pollution <u>subsequent</u> to the production of evidence as to its existence should not expect to find relief solely at the purse of the user of the noisy facility. If such relief is deemed to be in the public interest, to improve "the public health and welfare," than it appears reasonable that the public should pay for it, particularly when one considers the vastness of the costs and the relatively small base which would otherwise have to support them.

The argument may be made by proponents of an opposing point of view that factories which pollute streams are required to fund corrective measures, and that the costs involved are passed on only to their customers (read users); that pollution control devices on automobiles are paid for by the ultimate purchaser (read user) in the purchase price, etc., etc. While this is true, the relative fiscal load per individual is insignificant when compared to the ratios applicable in aviation, particularly commercial aviation.

If elected as an alternative, implementation could not be expected to commence prior to 1975 because of the necessity for finding means for financing, enactment of appropriate enabling legislation where needed, establishment of organizational means for accomplishment, inter alia. It is anticipated that the entire process would take at least 5 years to complete, due at least in part to the present unavailability of substitute housing and public facilities (schools, libraries, etc.) for the displaced populace.

As a <u>single</u> source of alleviation of the problems under consideration in this document, it is considered to be impracticable. (Ref. 6, et al)

b. Zoning of Undeveloped Land for Noise-Compatible Use Only

Use of this technique is an absolute requirement in the earliest planning stages of a new airport. As sure means of eliminating noise exposure to households it has no equal <u>provided</u> that it is exercised firmly, without exception and with no regression. Unfortunately, the history of activity in this sphere is replete with examples representing the complete antithesis of these requirements.

It has been considered by some that this quasi-judicial process may be considered to be a "taking" of property rights from the owner and that compensation therefor is due. This is a problem to be wrestled with by the legal experts. If there is shown to be a pecuniary loss to the property owner as a result of this type of action, compensation would be a cost associated therewith, to be borne by the airport authority. It is reasonable to expect that the administrative costs involved in the zoning/rezoning activity be borne by the agency exercising the land use control authority.

The effectiveness of this technique extends throughout the time frames discussed herein. Some jurisdictions have the authority at present in their land use ordinances to effect such actions for the purpose of noise prevention. Others would likely require additional enabling legislation, compacts among neighboring jurisdictions, etc. In still others, this situation is uncertain.

Nevertheless, notwithstanding the problems attendant thereto, it is deemed to be practicable as a partial solution to the problem. (Ref. 5)

c. Withholding of ADAP Funds in Absence of Adequate Land Use Planning

Here is a methodology which should have been employed years ago by the FAA and which would have stimulated (1) litigation to overcome what would be called "arbitrary and capricious" action on the part of the Federal government without legislative authority therefor and thus likely triggered the Congress into providing this authority, or (2) concerted honest effort on the part of airport sponsors to "clean up their own houses" in this context. There are no tangible dollar costs which can be assessed against this activity nor, in view of the intent of the Congress in enacting the Noise Control Act of 1972, should there be any reluctance on the part of the FAA to, at least, propound establishment of this policy at the earliest possible date. The Administrative Procedures Act being what it is, affected persons would be provided more than ample opportunity to be heard on the subject prior to the establishment of a regulation in this regard.

Its effect would be a lasting one and it is considered to be eminently practicable.

d. Compensation of Residents Within NEF 40 Contour Areas

Some effects of application of this strategy would be to decrease the number of noise complaints from the receiver population, and to provide, where practicable, a means for property owners to cause their premises to be insulated against the noise of aircraft. Yet against the yardstick of protecting the public health and welfare it does little, since sound insulation is not totally effective as a remedy for annoyance indoors and not at all effective for outdoor household activities. It certainly cannot be considered as a sole source alternative, but may have limited application in lieu of relocation in borderline cases.

Its methodology has been treated in two forms, so-called noise easements and property tax reductions.

(1) Noise Easements

The estimated cost of this alternative as a sole source technique is $1,100 million, based on 20% of the valuation of the property assessed in sub-strategy 3 a. infra. This cost would be laid on the airport operator and/or the local government, presumably to be recovered through increased (a) taxes on the airport, (b) charges to the airport users (airlines and others), or (c) passenger head taxes. Its application, as would the tax reduction alternative discussed below, would entail a periodic review (if it were a recurring payment) to ensure that the situation which called for the compensation continues to exist.

In order to accomplish this means, (which is not noise abatement under any extension of the definition of the term) action would be required at all levels of government to establish a uniform program. In view of what would be required in this sphere, it is considered that compensation action could not commence prior to 1976.

(2) Tax Reductions

All of the same arguments both for and against the foregoing concept are applicable hereto. In addition, there are a couple of points against this scheme which should be mentioned.

First, it does nothing at all for the renter, since by its very nature it is directed toward the property owner. This point is of large importance in areas such as New York, where a great percentage of those impacted by aircraft noise are apartment dwellers.

Second, the dollar amounts to each owner would not appear to be large enough to be anything more than a token payment for annoyance.

On the basis of the foregoing, for limited application in concert with other strategies, 3 d. (1) is considered marginally practicable and 3 d. (2) is deemed impracticable. (Ref. 5.)

4. Service Limitation Strategies

a. Curfew - All Flights

This subject is one which is anathema to the airline operators, faced with the specter of large units of airborne hardware being forced to stand idle for 37% of the 24-hour day when, at least over certain routes, these aircraft could be utilized to produce revenue. It is an especially grim prospect to the large movers of air freight, whether they be an all-freight operator or a combination passenger-cargo carrier. Much of the all-cargo transport activity transpires during the night hours, which provides the major incentive to a shipper -- next-day delivery at any major terminal in the country.

There is a considerable volume of eastbound non-stop, and one-and-two-stop trans-continental passenger service which would be disrupted by application of a curfew, since most of this activity is between 10:00 P.M. and 7:00 A.M. At least two airlines (Delta and Eastern) have a large volume of passenger flight movements during the early morning hours; one of the busiest hours of the day in respect to departures from Atlanta Airport is between 6:00 and 7:00 A.M. Traffic between the New York area and the San Juan and South Florida terminals is also rather intense during the normal periods associated with curfews.

Lest one start to feel that the foregoing is a sales pitch against the application of a curfew, be assured that it is purely a cursory statement of the current situation in respect to present (and presumably projected) flight activity in this country during late night and early morning hours.

Because of the manner in which NEF values are constructed, (and I am not taking issue at this juncture with their construction parameters) the elimination of flight operations between the hours of 10:00 P.M. and 7:00 A.M. would drastically lower each NEF contour in size at some major metropolitan airports, particularly JFK, ORD, MIA, LAX, SFO and ATL. It is inconceivable, however, that the flight activity accomplished during these hours would not be accomplished, were a curfew instituted. The cargo must be moved -- the remainder of the day's passenger flights will not adequately accommodate the available passengers -- the net result would be a rescheduling of activity into already crowded earlier or later hours, causing additional airport/airspace congestion (and in some cases over-capacitation). Yet the total EPNdb effect on the public would be the same.

What would result would be a serious inconveniencing of a substantial segment of the traveling public, additional fare costs (since additional airplanes would be required to accommodate passengers and, in some instances, cargo), elimination of the alternative of air travel to those who can only afford it on the basis of lower dollar outlay vs. unconventional flight hours in some markets, and, as previously indicated, additional delays to flights caused by overcapacitating terminal area airspace and runways.

Yet on the other hand there is the constraint of protecting/preserving the public health and welfare. Doubtless the health of presently noise-impacted householders would be improved if they were not subject to the stresses associated therewith at night. Without appearing to disregard this facet of the problem, an overriding concern might be in this case the welfare of the traveling and shipping public as well as that of the operators. Attempting to reconcile these deverse interests with a single-edged sword labeled "excision" is a fruitless exercise, for it deals with irreconcilable extremes. What appears to be a more reasonable solution to this dilemma is discussed in the next subsection of this report.

To summarize, a complete curfew on flight operations between 10:00 P.M. and 7:00 A.M. would reduce NEF 30 and 40 contours by an estimated 60-75%, mostly in major terminals where flight activity between these hours constitutes a significant portion of the total activity, thereby increasing NEF values. Its noise-abating effect would be felt by approximately 2.7 million people, or about 40% of the total population affected by NEF 30 and 40 exposure.

Its costs are impossible to assess realistically because of the variety of options which might be exercised by the operators/users. Its limitations have been heretofore categorized and do not need summarization. It could be effected immediately, but its disruptive effects would ricochet throughout the remainder of the decade. It is deemed to be impracticable as a single source solution to the problem.

b. Curfew - Non-quieted Aircraft

As an alternative to the foregoing strategy, consideration was given to a curfew which would be applied to those aircraft which had no undergone any type of sound-reducing retrofit as of a certain date. This technique alone would provide a large degree of relief to affected households and, further, provide a needed incentive to the airlines to avoid operating penalties by proceeding smartly with an appropriate noise source abatement technique.

This strategy should also provide the option, where a suitable non-impacted alternate airport is available serving the same city, for use by unmodified airplanes of the alternate airport during curfew hours. There are very few cities, however, to which this option would be applicable. West Palm Beach might be substituted for Miami, Dulles for Washington National, Oakland for San Francisco International -- those are the only three which come to mind readily.

In any event, this scheme is a relatively palatable alternative to the plan discussed in Section C4a <u>infra</u>. It is practicable, with qualifications, and in and of itself could be applied with an effective date established one year after the beginning of a source abatement strategy. Its costs are minimal and its indirect effects far-reaching.

c. Capacity Limitations

Another service restriction strategy which was examined was the reduction in number of total flights between city pairs served by two, three or more carriers. Examples are: New York-Boston, New York-Washington, New York-Chicago, Chicago-San Francisco, San Francisco-Los Angeles, New York-Miami, etc. The total reduction in NEF number achieved as a result of the application of this means would be insignificant, since this type of restriction has already taken place once, a few years ago. <u>If</u> it were found that load factors were averaging below 75% for <u>all</u> flights between one city pair, then consideration might be given to this technique. However, if at Los Angeles, for example, with its daily operations total in the area of 1225, it has been estimated by the Director of Airports of Los Angeles that there would be a reduction of ten operations by this means, which would affect the NEF numbers by a value of 0.03 for day or evening flights and 0.5 for all night time flights.

At LaGuardia Airport, a reduction of twenty operations per day or evening (the only periods where such reductions could be practically be accomplished) the resultant NEF would be 0.05.

As a result of the foregoing calculations no further consideration was given to the strategy.

III. FINDINGS

As has been indicated previously, no single strategy by itself is considered to be practicable in order to alleviate the airport/aircraft noise problem in a timely manner, or for all locations. Rather, a combination of strategies must be applied, with some variations chosen to suit specific locations or types of situations. Some of the individual strategies previously classified as impracticable in toto change their characterization when considered in combination with others.

In deriving the estimates of improvement expected from the combinations hereinafter expounded upon, each selected source abatement and operational procedures strategy was examined to determine, if possible, its benefits expressed in EPNdb. These values were then summed, and the resultant total was cross-matched to equivalent percentage reduction in NEF 30/40 contour reduction. This computation method appeared to create an unconservative degree of decrease; therefore, the process was repeated using the root sum square method and the values derived therefrom again crossmatched. The results of both methods appear in Table I, along with a display of the effects of engine nacelle acoustical treatment alone.

The limited number of choices displayed in Table I presages the options which this report will recommend for implementation. These options are in the source abatement and operational procedures areas only. Subsequent to their application there may remain a "hard core" area around many airports which has not been and will not be relieved by these measures. The extent of these areas may only be estimated in toto by the application of the numbers used in this report. It is anticipated that the size of the remaining problem areas will vary as each airport varies in its environs.

These areas and their population should be treated by a land use strategy, probably relocation, and conversion of the affected properties to noise-compatible uses. The costs associated with acquisition, along with the costs of the other recommended alternatives, are shown in Figure 2, which also indicates the time frame over which each alternative may be expected to be implemented.

As a spur to the air carriers and other direct users of the airspace to implement a viable source abatement strategy, action appears advisable on the part of Federal authorities to propound rule-making which would establish, at a reasonable date, a curfew applicable to flight operations of aircraft whose engines have not been appropriately retrofitted.

In the fiscal area, a requirement exists for funding large expenditures for retrofitting jet engines, as well as in land acquisition and relocation of impacted households. This is aimed at protecting the public health and welfare, and as such, means should be found for financing a reasonable part of these costs from general revenue funds of Federal, State and local governments.

IV. CONCLUSIONS & RECOMMENDATIONS

A. The cost/benefit relationship of all source abatement strategies except engine nacelle acoustical lining does not justify their further consideration in the near term. However, continued and intensified effort is needed to insure that new airplanes entering the fleet, and especially their engines, are designed and/or treated to the maximum extent practicable toward the reduction of noise.

B. Engine nacelle acoustical lining produces a significant reduction in source noise at a not unreasonable cost, provided that this cost may be shared by the public along with the user.

It is therefore recommended that a program be instituted wit without delay to require the acoustical treatment of JT3D and JT8D engine nacelles as delineated in the various references herein.

C. The sound-reduction values achievable by nacelle treatment can be increased significantly by combining that approach with the early implementation of certain operational procedures.

D. There is no difference between the reduction values achieved by two-segment approaches and higher glide slope angles.

E. The small gains apparent from the use of two segment approaches, as opposed to the election of the use of a higher transition altitude, do not justify the airborne and ground installation costs involved.

F. Because of the diversity of size, shape and location of problem areas among the various noise-impacted airports, it may be more practicable at some locations to adjust the glide slope angle upward, utilizing a higher transition altitude in association therewith, and at others to rely solely on the latter operational procedure.

It is therefore recommended that, as appropriate to each airport concerned, the operational procedure/s discussed in f. supra be instituted at an early date.

G. As a result of the foregoing, the present NEF 40 contour areas will be markedly reduced in size and, therefore, population.

It is recommended that land use strategy a., relocation of persons within NEF 40 contour areas, be instituted as soon as a firm determination can be made regarding the extent of the remaining impact area.

It is further recommended that costs involved in accomplishment of this recommendation be borne in considerable part by the public at large.

H. Zoning of undeveloped land for noise-compatible use is an essential strategy in the prevention of damage to the public health and welfare.

It is recommended that necessary legislation be enacted which will ensure that this action is taken in respect to new as well as existing airports.

I. Withholding of ADAP funds in the absence of adequate land use planning will force airport and land use control authorities to take appropriate steps to prevent loss of funds.

It is recommended that rulemaking be promulgated by the Federal Aviation Administration which will direct the withholding of ADAP funds in the demonstrated absence of land use planning in respect to noise.

J. Curfews per se are unduly restrictive, and often costly. However, curfews intelligently and selectively applied may be utilized to achieve beneficial results without undue expense.

It is therefore recommended that action be taken on the Federal level (so as to ensure standardization of application) to institute, as of a reasonable effective date subsequent to the inception of the recommended engine nacelle retrofit program, a curfew on all flight operations in terminal areas between the hours of 10:00 P.M. and 7:00 A.M. local time, except for those aircraft whose engines (a) meet FAR 36 certification noise emission standards, or (b) have undergone nacelle acoustical treatment.

The alternative strategies recommended herein are discussed further and displayed graphically in Appendix A hereto.

APPENDIX A

The alternative strategies chosen in the report have been considered in this Appendix relative to their chronological impact, particularly their pecuniary impact. The results have been plotted on Figure 2, Costs and Scheduling of Recommended Alternatives, with the costs scaled down to their dimensions as reduced by application of the chosen strategies.

These data need little explanation. They represent the costs of the alternative to the entity or entities required to finance them on an annual and a cumulative basis. The figures contained in parentheses are those associated with a fast-schedule engine acoustical treatment program. The difference between these costs and the "moderate" schedule program costs is the amount of overtime and extra labor compensation involved.

All of the time framing shown presumes reasonably expeditions actions on the part of all those from whom action is expected; i.e., legislatures, both state and federal, municipal governments, airport operating authorities, air carriers, engine and airframe manufacturers, etc. Shilly-shallying and extended debate on the problem or its recommended solutions should have transpired long since. Now is the time for action, not words.

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THE GEORGE WASHINGTON UNIVERSITY
Program for Policy Studies
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EPA Contract No. 68-01-1834

EXAMINATION OF SELECTED ALTERNATIVE MEANS

OF

ACHIEVING SIGNIFICANT AIRCRAFT/AIRPORT
NOISE REDUCTION

TABLE I

EFFECTS OF SELECTED STRATEGY COMBINATIONS ON NOISE REDUCTION AND POPULATION RELIEF

STRATEGY 1/ COMBINATION	TAKEOFF/ LANDING	REDUCTION IN EPNL		% REDUCTION IN AREA		NEF CONTOUR NUMBER	POPULATION RELIEVED (Millions	
		2/	3/	2/	3/		2/	3/
A + 1	LNDG	8.7 - 16.5	7.2 - 9.62	74 - 94	67 - 77	30	4.575 - 5.811	4.142 - 4.761
A + 3	LNDG	18	18	95	95	40	.587	.587
A + 2	LNDG	13	9.22	84.5	75	30	5.224	4.637
A + 2	LNDG	18	18	95	95	40	.587	.587
A + 4	TO	7.5	5.47	69	57	30	4.266	3.524
A + 4	TO	18	18	95	95	40	.587	.587
A ONLY	TO	2.8		36		30	2.226	
	LNDG	7		62.4		30	3.858	
	TO	5.4		57		40	.352	
	LNDG	18		94.5		40	.584	

1/STRATEGIES
- A = Engine Nacelle Acoustical Treatment
- 1 = Steeper Glide Slope
- 2 = Higher Transition Altitude
- 3 = Two-Segment Approach
- 4 = Thrust Reduction on Climbout

2/ Adding values derived from technique combinations shown in first column
3/ Determining square root of sum of squares of values from technique combinations shown

STATEMENT OF FUNCTIONS OF NOISE MEASUREMENT TECHNIQUES

Prepared by

Edward D. Studholme

May 15, 1973

for

THE GEORGE WASHINGTON UNIVERSITY

Program of Policy Studies in Science and Technology

Task Group 1 - Legal and Institutional Analyses

EPA/ONAC - § 7 - Aircraft/Airport Noise Abatement /Prevention

EPA Contract No. 68-01-1834

STATEMENT OF FUNCTIONS OF NOISE MEASUREMENT TECHNIQUES

Although the measurement of noise in terms of its physical properties is a well developed science, as are the techniques employed in predicting changes in sound pressure levels with certain variations in the noise source and the surrounding environment, the predictability of the human response to these sound levels is a good deal less absolute, and consequently the establishment of standard measurement criteria is difficult. This issue is further obfuscated by the proliferation of criteria adopted and utilized by different federal agencies, states, and countries. In correlating scientific findings concerning the effects of noise on people, the investigator is confounded by the use of such abbreviations as dB, dBA, PNdB, EPNdB, AI, NI, Q, NNI, TNI, NEF, CNR, and CNEL. Fortunately, much of the resulting confusion may be eliminated for those of us who have little technical background by examining the specific <u>functions</u> that each measurement technique serves.

Basically, each technique may attempt to measure

1) The sound <u>pressure</u> emitted by a single source (dB),
2) The <u>loudness</u> of a single source (dBA),
3) The <u>noisiness</u> of a single source (PNdB),
4) The noisiness of a single source corrected for the <u>length of exposure</u> and pure tones present for a single event (EPNdB), and
5) The level of community annoyance created by a <u>series</u> of noise events corrected for the time of day during which they occur (CNR, NEF and CNEL).

Thus, the measurements most commonly employed in the U.S. may be presented in a table, as follows:

Evaluation Criteria / Unit Of Measure	Sound Pressure Emitted By A Single Source	Human Perception Of "Loudness" Of A Single Source	Human Perception Of "Noisiness" Of A Single Source	Corrections For Pure Tones & The Duration Of A Single Noise Event	Corrections For The Number Of Daily Events "Community Annoyance"	Corrections For The Time Of Day
dB	Measured On Sound Level Meter "C" Scale					
dBA		Measured On Sound Level Meter "A" Scale				
PNL			Measured On Sound Level Meter PS PNdB			
EPNL			Measured On Sound Level Meter As EPNdB	Generally ±2 Adjustment To PNdB		
CNR					Uses PNdB	Operations Weighted For 2200-0700
NEF					Uses EPNdB	Operations Weighted For 2200-0700
CNEL					Uses dBA	Operations Weighted For 1900-2200 & 2200-0700

The three composite measures of community annoyance, CNR, NEF, and CNEL, are presented in the order in which they have been developed. CNR was developed and utilized during the middle 1960's, and both the FHA[1] and VA[2] adopted it as a criterion to be used in evaluating whether residential properties qualified for Federal mortgage assistance.

With the derivation of the more sensitive EPNdB from PNdB, NEF emerged as the more generally accepted technique for evaluating the impact of aircraft noise on communities and has been adopted by HUD Circular 1390.2, as amended.[3] Both the FHA and VA have subsequently adopted NEF, and it has been the most extensively used measurement technique in the U.S. to date.

CNEL was developed by the State of California for use in its adopted airport noise regulations,[4] and may prove to be both more useful (dBA is a measurement unit uniquely compatible with other noise sources and standards) and more accurate (the weighting of operations from 1900-2200, as well as from 2200-0700, appears to have merit) than NEF.

However, NEF has proved to be a valuable tool in the field of land use planning, and the vast majority of data concerning the compatibility of community development near specific airports in the country have been developed and presented utilizing the NEF methodology. For this reason, NEF has been used almost exclusively in analyses which have required data samples and forecasts for a large number of airports.

FOOTNOTES

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2. Veterans Administration. Letter no. 26-65-4, May 5, 1965.

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AN EVALUATION OF
POLICY ALTERNATIVES FOR
AIRPORT NOISE ABATEMENT

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the EPA/ONAC study of
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ABSTRACT

The problems of noise associated with airports have been identified as issues of local and national concern. The causes of these problems and potential technological solutions are described. Traditional and modern judicial theories as well as legislative approaches and their limitations are also examined. In addition to continuation of the present policy, five major policy alternatives are identified: three technical, one legislative and one judicial. These alternatives are (1) operational changes using a $6^{o}/3^{o}$ glide slope for landings, (2) nacelle acoustic treatment for present aircraft, (3) new engines on new aircraft available in 1980, (4) imposition of a 10 p.m. to 7 a.m. national curfew, and (5) liberalization of judicial policy granting more and larger damage awards. Social Value Function analysis is explained and applied to evaluate the dollar and non-dollar-quantifiable costs and benefits that accrue from the major alternatives and their combinations. As a result, certain minimum low-cost actions are recommended. In addition, the political choice between more costly alternatives is clarified and an institutional structure proposed to facilitate the choice.

TABLE OF CONTENTS

I. INTRODUCTION

Airport noise control has become an issue of both local and national importance. Communities not only object to present noise but also fear future increases. Their objections have gained mushrooming political support and, as a result, the development of new airports and/or the expansion of present facilities has been stopped in many areas of the country.

In the joint Department of Transportation - National Aeronautics and Space Administration report on Civil Aviation Research and Development, the importance of this public concern was recognized.

> The impact of civil aviation on the environment is evident in the public concern regarding noise, air pollution, esthetics, ecological disturbances, and meteorological changes. Of these effects, <u>noise is judged to be the most important and presently a critical constraint to the future growth of aviation</u>.... [I]ncreasing resistance to aircraft operations can be expected at the very time these operations should increase significantly to meet the growing travel demand.[1] (emphasis added)

The basic cause of the airport noise problem is directly related to the technology of the aircraft or, more specifically, the turbojet engine used to propel most modern aircraft. But solutions to the problem must rely heavily on legal, political and economic considerations as well as technology.

There are a multitude of options available but to date they have never been compared in any systematic way to evaluate their relative effects on the local community, the air industry and the traveling public. The assessment task is to select the best solution to the existing problem from a number of specific policy alternatives. The difficulty is in defining "best". As in any environmental area, quantifying social, non-economic values is highly subjective. The National Academy of Science recognized the relevance of the social costs and the difficulty in comparing them with other economic factors when it stated in a recent report

> ...Almost without exception, technological developments will affect some people or interests adversely and others beneficially, and there simply is no agreed-upon algebra by which one can neatly subtract the pains from the pleasures in order to arrive at a net index of social desirability.(2)

To provide that missing "algebra", a Social Value Function technique will be used. The economic difficulties underlying the assessment process will be examined as well as the technical, judicial and legislative alternatives available to control airport noise. Social Value Functions will then be computed for promising alternatives and the results compared in detail. Finally, the political realities in adopting each of the most promising alternatives will be evaluated and the ones with the highest probability of success identified.

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2. Anon. Technology: Process of Assessment and Choice. National Academy of Sciences Report to the House Committee on Science and Astronautics (1969), p. 20.

II. THE SOCIAL VALUE FUNCTION

To be effective, any assessment technique must

1. force the assessor to consider all foreseeable implications of the proposed change;
2. quantify these foreseeable implications; and
3. provide a method of comparing the results with those of other alternative policy choices.

The first two of these objectives are relatively straightforward; however, to date there has been no adequate method of comparison. This paper establishes a "Social Value Function" to make the third objective not only possible but practical.

The Social Value Function is an outgrowth of the economists' Social Welfare Function[1] but with two major differences. First, the Social Welfare Function assesses the absolute value to society of some course of action while the Social Value Function studies relative effects of different policy alternatives. Therefore, using the Social Value Function, it is not important to come to an exact formulation of all possible factors so long as the same method of formulation is used for each alternative. Minor errors would bias all results in the same direction and therefore not affect relative results.

Second, the analysis used in constructing the Social Value Function starts with the premise that, although theoretically possible, it is impossible from a practical standpoint to assign dollar costs and benefits to all possible social impacts of a planned course of action. In the development of the Social Welfare Function, the economists realized this problem and reformulated their equation to eliminate non-dollar terms.[2] The Social Value Function is deliberately formulated in both dollar and non-dollar terms to emphasize the necessity of valuing both types of costs and benefits.

Identification of Foreseeable Implications

The first step in formulating the Social Value Function is to identify the cost-benefit relationships that presently exist for the problem being studied. One way to identify these relationships is to use elaborate checklists which enumerate general categories and types of impacts which could apply to a range of problems.[3] The analyst relates these general lists to his specific problem to see which classifications might apply. Although these lists are merely an outline or starting point in assessing a particular problem, they force the person performing the assessment to consider a large number of possible impact areas. Another successful way to identify cost-benefit relationships is to assemble a group of qualified experts to prepare lists of important factors from their combined experiences and backgrounds.[4]

Once potential impacts are identified, their relative importance must be decided. Philosophically, chains of causation can go on indefinitely, but for practical applications limits must be placed on how many possible impacts will be evaluated. As a general rule, evaluating a potential impact is not practical when either:

1. causation is no longer clear or
2. the potential impact results from a number of causes and the contribution of the problem being studied is no longer significant.

Quantification of Impacts

Once foreseeable implications or impacts are identified, they fall into three categories:

1. those that can readily be assigned a dollar value;
2. those that could be assigned a dollar value if sufficient data were available; and
3. those that cannot be accurately measured in monetary terms.

In the first case, dollar values will be used. In the second, dollar values will be assigned where data can be found or constructed. Often the relative changes in these impacts can be predicted in dollar terms even though the absolute number is inaccurate. For example, a recent article cited the increase in fuel costs due to aircraft noise abatement procedures.[5] This number is valuable even though the absolute fuel costs are unknown. However, when even relative dollar values are unknown, impacts of the second type will be treated like the third.

The third type of impact must be evaluated in terms of value judgements. In this case in particular, it may be impossible to assign an absolute value to the impact. As a recent study stated,

> It must be recognized that such terms as "harmful" or "important" are charged with value judgements and are profoundly affected by the prevailing concept of man and his relation to the environment. This does not preclude objective analysis, but it throws light on what an objective analysis means in this context. An objective analysis in this sector of problems is one that at all times takes account of the fact that the meaning and weight of the terms of analysis vary with the differences in the basic concept of man and his relation to the environment.(6)

With this admonition in mind, the Social Value Function is designed to consider community value judgements. These are assessed through community surveys to determine what impacts are considered important, how important they are in relative units, and how much a unit of change would be worth to each individual in the community. Again it must be stressed that exact values are not as important as the relative changes resulting from different policy alternatives.

Comparison of Alternative Policy Choices

Once all the variables are identified and quantified, the Social Value Function is constructed for the existing situation. The various policy options are reviewed and those practically or politically unacceptable are eliminated. (For example, an option for the control of airport noise based on the nationalization of the entire air system could be dismissed at this point in time.) Then for each policy option remaining, the changes to the existing situation are assessed based on the amount of change, the number of individuals affected and the value of the change to each individual. To make this task manageable, the individuals are collected into interest groups (i.e. conservationists, airport neighbors, local businessmen, etc.) and group values used where possible. In many cases, the groups affected will be the same for all options, so only the amount of change is important.

The policy options are then evaluated in terms of their dollar and non-dollar components. Those which have the higher benefits in each category are reviewed for ease of implementation, political acceptability, economic feasibility, etc. Theoretically, one option will stand out as being superior to the others. Practically, one or more options will be selected and proposed for implementation.

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III. THE UNDERLYING ECONOMIC PROBLEM

One of the objectives of policy assessment is the selection of a plan that is economically efficient. Therefore, the value of airport noise reduction must be balanced against the cost of obtaining it. The first few increments of noise reduction are relatively inexpensive. But at some point further noise reduction requires major investment in new equipment, and perhaps in new technology, to achieve the lower levels. Conversely, when community noise levels are high and bothersome, each unit of relief is worth a great deal. As the overall noise level gets lower, the value of further noise reduction is less.

Economists have stated

> The optimal level of pollution...is reached when the costs of further reductions equals the benefits accruing to society from further reductions. As a corollary, the means of reducing these... effects must be achieved in the least costly way possible.(1)

In Figure III-1 at Point A, the value of a further unit of reduction is equal to the cost of obtaining that reduction. This is the point of maximum community value. If the industry is compelled to implement further noise reduction measures (Point B), the cost of each

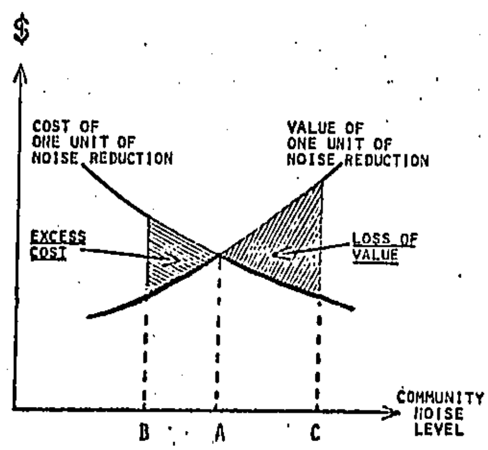

Fig. III-1 Noise Reduction Trade-Offs

unit exceeds its value to the community. If the noise limit is set too high (Point C), the costs of further noise reduction measures are less than the value obtained. In the first case, the noise limit should be raised since the excess cost is wasted. In the second case, the limit should be lowered since the community would gain more than the noise reduction would cost.

Determination of the cost of noise reduction is not easy, but reasonable estimates can be obtained by projecting the costs of hardware development, installation, etc. Industry has a great deal of experience in predicting these types of expenses.

Determining the value of noise reduction is considerably more difficult. How are intangibles like loss of sleep, bad television reception, and general annoyance to be measured? Since direct measurement is all but impossible, it is usually assumed that these factors are reflected in a decrease in land values. However, there are other influences which may conceal the effects of noise. People who work at the airport may value convenience more than they object to noise. Industrial parks and hotels seek land near an airport since access to transportation is vital to their business. Beachfront land is at a premium regardless of noise levels. As a result, land values near an airport often go up even though the property is less suited to average residential use. This was highlighted in a study sponsored by the National Aeronautics and Space Administration which concluded

> ...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.(2)

Since it would be highly impractical to set different noise levels for various pieces of property depending on each owner's subjective values, some sort of community average value must be used. If the resulting noise level is too high for a particular person then, in theory, he should sell out to someone who does not object. Over some period of time, the proper balance would occur through the operation of the marketplace. This is what has happened over the years with the railroads as people who were bothered by the noise sold out and people or industry who wanted the convenience bought in.

No matter how correct this solution may be from an economic viewpoint, it is not acceptable politically. Although aircraft noise has been an isolated problem from the earliest days of aviation, it is only since the widespread introduction of jet aircraft that major community disruption has occurred. People who once were only marginally aware of airport activity now find themselves subjected to increasingly higher noise levels. It violates our innate sense of justice to tell these people to move if they don't like it. Politicians see this as an area where they can win votes by showing their support for both the little man and the environment. But noise restrictions imposed by the political process can only be set by educated guesses and are bound to differ from the noise levels dictated by economics.

In addition to the difficulties in determining noise levels and their relative costs, it is necessary to decide how these costs should be allocated. In an ideal market system, the buyer of a product or service should pay all the costs of its production including the social damages caused by noise, pollution, etc. If the price of each item on the market reflects its true cost, then the buyer's selection of one item over another indicates their relative values to him and, in the aggregate, to society as a whole.[3]

However, an ideal market system is not possible. There are too many factors that enter into the problem. First, it is difficult to assess all the true costs since, as mentioned above, social damages are very hard to compute.[4] Second, a buyer cannot possibly know of all the products or services available on the market; therefore, he cannot weigh all possibilities.[5] Third, buyers act in response to present values without being able to fully anticipate future worth.[6]

One role of government is to attempt to correct these market deficiencies, keeping the national interest in mind.[7] Therefore, the government subsidizes air service to small communities where there is not enough market demand to meet out-of-pocket costs, much less social costs. Subsidies are paid to the ship-building industry. Housing loans are guaranteed for veterans, another form of subsidy. The government undertakes these programs because it feels that community development should be encouraged or because a ship-building industry could be needed in time of war or because it feels that private housing is a worthwhile goal. Of course, when the government acts, it is not the government but society as a whole who pays through the tax structure.[(8)]

Thus there are three acceptable options as to who should pay for noise damage. If the market process is to be encouraged, the users of the air system should pay. If social values are paramount, society in general should pay. Or some workable combination of the two should be devised. But none of these alternative sources has been assessed with the damage to date. Until now, the small portion of society that lives near the airport has borne all the social costs of the system. Many argue that this is not unjust since this portion shares in the benefits that accrue to society from air service. But this ignores the physical realities of the situation. The benefits of air service are diffuse and have little relationship to distance from the airport while the burdens of noise, pollution and congestion are highly concentrated in the airport's immediate vicinity.

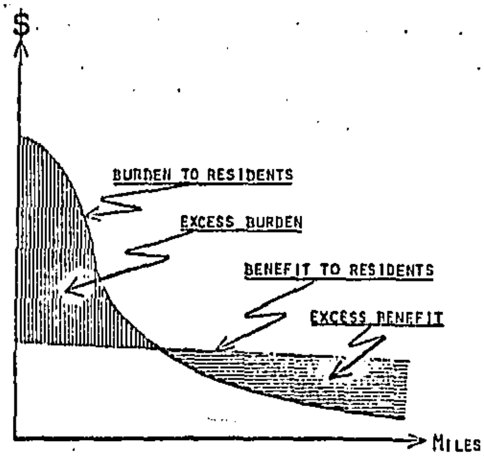

Fig. III-2 Distribution of Burdens and Benefits of Air Service with Distance from the Airport

No matter which option for the distribution of the airport noise cost is selected, it has to be more equitable than the present situation. In any case, the excess burden must be lessened either by reducing it through technology or by transferring some of the excess benefit as compensation to those who bear the loss.

Although the application of the policy assessment process to these options should strive for economic efficiency, it must also somehow factor in both the difficulties in determining economic values and the realities of the political system. However, in designing a policy assessment method

> ...the many faults of that system [of markets, prices and private enterprise] should not be allowed to obscure its virtues, and any plan devised to improve our management of technology change should "make maximum feasible use of this ingenious mechanism for allocating resources and calculating effects."(9)

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IV. TECHNOLOGY AND ITS LIMITATIONS

Before different policy options can be assessed, the available technological alternatives must be identified, along with their limitations. For airport noise control, techniques of noise reduction can be considered as they relate to the sound production processes:

1. generation -- the physical activity producing the sound at its source;
2. transmission -- the passage of the sound from source to receiver; or
3. reception/reaction -- the psycho-physical process through which the listener recognizes the sound and subjectively classifies it as noise.

Reduction at the Source

The jet engine is the primary generator of aircraft sound. The majority of this sound is produced by either the interaction of the high-speed jet exhaust gases with the relatively still air through which the plane passes or by the compressor blades inside the engine itself. The first is characterized by the roar at take-off, while the second is most noticed as a high-pitch whine during landings. Effective noise reduction must control both.(1)

Hardware Changes -- Exhaust sound is primarily a function of the speed of the gases. Early attempts to reduce this sound through the use of nozzles and suppressors did cut down the speed of the exhaust and thus lowered the over-all level. However, they also raised the pitch of the sound into a range where the ear is more sensitive, so did little to reduce annoyance.(2)

The most successful approach to lessening exhaust sound is through the use of the "high-bypass" engine now being introduced on the Boeing 747, the Douglas DC10, and the Lockheed L1011. A certain amount of air passes through the engines without being combined with fuel and ignited. The ratio of this "by-passed" air to that used in the combination process is called the "bypass ratio" and for engines designed in the 1950s and 1960s is typically 1 or 2 to 1. In the "high-bypass" engine, this ratio is increased to 6 or 10 to 1 which results in more air being moved but at lower exhaust velocity. Because exhaust speed is lowered, the exhaust sound from these new engines is much less than from a 1960 engine of equal power. As a result, the larger "wide-body" jets are actually quieter than the smaller B707 or DC-8 class planes presently in service.

> The new wide-body transports have continued a trend toward achieving reductions in community noise levels....The JT9D [engine used on the 747] has more than twice the thrust of the original turbofan engines, yet the latest 747 with treated nacelles has noise levels [subjectively three times] lower than aircraft powered by the initial turbofan engines....(3)

Hamilton Standard Division of United Aircraft Corporation presently has under design an engine with a bypass ratio of 25 or 30 to 1. Such an engine could be operational in the late 1970s and would result in further significant exhaust sound reduction.(4)

There are also techniques for reducing the compressor sound of an engine, primarily produced by the interaction of the air stream in the engine with rotor blades and vanes of the compressor--an effect much like that used in sirens. Tests have shown that significant noise reduction can result from varying the location and number of these components and their turning speed.[5] This type of technology was also used in the high-bypass engine of the 747 and resulted not only in lower sound levels, but also in a lower-pitched sound which is not as annoying.

As engine sound is reduced, the land area exposed to airport noise is correspondingly reduced (see Figure IV-1). If older aircraft presently flying could use engines designed today, the exposed land area could be reduced by a factor of 10. If engines available at the end of this decade were available now, the exposed land area could be reduced by more than a factor of 20.

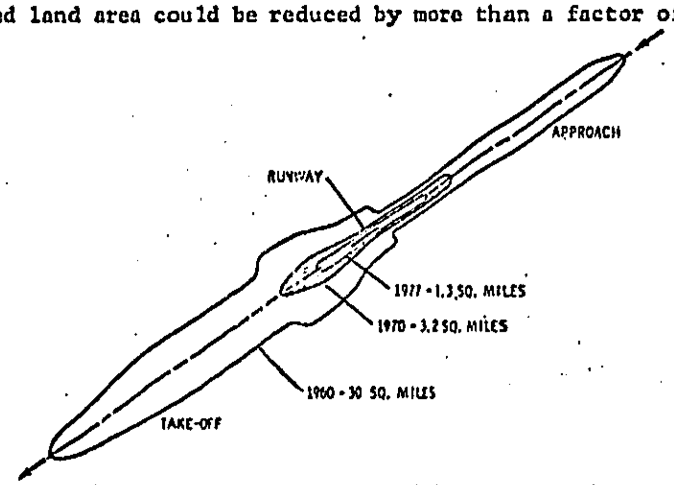

Fig. IV-1 Land Area Exposed to High Noise Levels (90PNdb) by Aircraft Designed with 1960, 1970 and 1977 Technologies[6]

Although technology has produced quieter engines for aircraft presently entering service and promises further noise reduction in the future, the bulk of the present fleet consists of jets designed without these improvements. Some of these are ten years old or older and will be retired from major airline service as the jumbo jets are purchased. However, a large number of planes in the fleet have many useful years of service remaining. Scheduled carriers are expected to have 553 narrow-bodied four-engine jets remaining in their fleets in 1975 and 428 in 1980.(7) Forced retirement before these planes are fully depreciated would represent major economic waste, particularly now when the industry has already made major financial commitments for wide-bodied aircraft purchases.

Programs that would re-equip the present aircraft with the new technology engines have been considered. However, because of their large size, the engines actually used on the wide-body class of aircraft could not be installed in present aircraft without major structural changes. A better solution would be to design an engine that employed the new techniques and was also compatible with present aircraft structures. However, such a program would probably require four to five years from the start of the design to its certification as safe by the Federal Aviation Administration (FAA). By that time, many more planes in the present fleets would be close to retirement by the trunk carriers. Although older planes may fly many years after their retirement from mainline passenger service, either as freighters, charters or primary equipment for smaller carriers, their use at the major hub airports where serious noise problems exist may decrease drastically. Therefore, re-engining would serve little purpose.

A second approach would reduce both exhaust and compressor sound levels by redesigning the fan assemblies of present engines. Although promising, this approach would be expensive and time-consuming and require recertification of the engine.

Another technique seriously considered is treating the engine housing and mounts with sound-proofing material. The National Aeronautics and Space Administration has sponsored several programs to study this approach and indications are that substantial reductions can be made, primarily to the fan whine. The details of implementing such a program, including FAA certification, are shown in Figure IV-2.

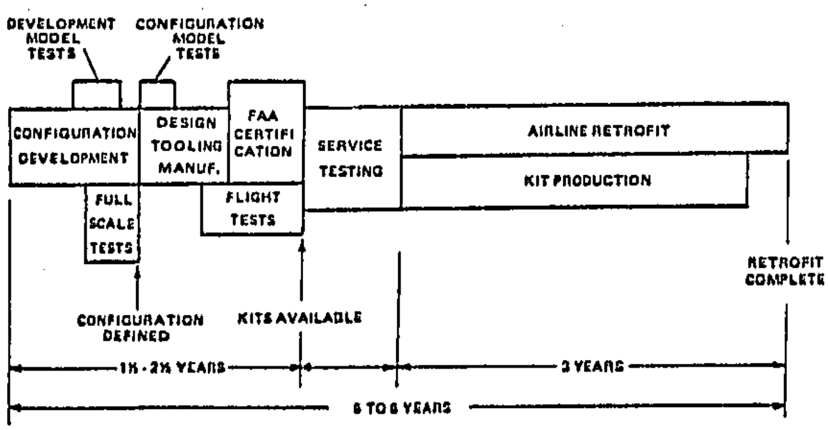

Fig. IV-2 Nacelle Retrofit Schedule[8]

Although it would take several years before such a program could be implemented and early estimates of the cost were high ($800 to $2,500 million),[9] experience is showing that the actual costs are now lower. The resulting noise reductions will reduce overall community annoyance. Annoyance reduction in high noise areas, however, may not be very great (see Section VII).

Operational Changes -- The major operational change that affects the sound at its source is a power cutback. Although this procedure was fought by the pilots in the early 1960s for safety considerations, cutbacks over densely populated areas are usually standard today, unless in the pilot's judgement adverse conditions make it unsafe to do so.[10]

However, the power cutback reduces the plane's rate of climb. In addition to adding to operational costs, this spreads a lower noise over a larger area. At full power, the plane would make more noise close to the airport, but would have climbed high enough not to affect outlying areas. With the cutback, there is some relief close in, but areas that did not have a problem now complain. In effect, the noise burden has not been lessened over-all but has shifted to a larger segment of the community (see Figure IV-3).

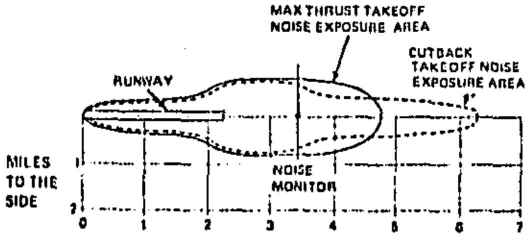

Fig. IV-3 Effect on Noise of Take-Off Procedures (90 EPNdb Contours)[11]

Reduction of Transmission

There are two ways of reducing sound by affecting its transmission. The first is by putting more distance between the source and the listener, letting natural dissipation decrease the sound level. The second is by blocking the transmission through sound-proofing techniques.

Dissipation Through Distance -- The energy of sound falls off proportionately to the square of the distance between the source and the listener. If the distance is doubled, the energy decreases by 1/4. If the distance is tripled, the energy is decreased by 1/9. However, a person perceives that the sound level has merely been halved(12) when the energy has actually been decreased to 1/10 its prior level. Thus, a distance increase of slightly more than a factor of three generally will seem to halve the sound (although wind direction, the nature of the terrain and atmospheric conditions may vary this effect). Since air does not transmit the more annoying high-pitched tones as readily as lower ones, the annoyance may decrease slightly more rapidly than the actual sound level.(13)

Land acquisition is perhaps the most successful way to increase the distance between the aircraft and the listener. The airport buys enough land to allow the airplanes using the airport to climb high enough to dissipate most of their noise before crossing the airport boundary. Although this technique has been used for new airports in open areas (e.g. Montreal's new airport has a land area of 80,000 acres), it is prohibitively expensive for older airports in developed areas. The cost to the Los Angeles International Airport alone for the purchase of property subjected to high noise levels has been estimated to be $1.6 billion.[14] In addition, the taking of large tracts of land in existing communities might actually increase the "noise impact", since the required condemnations may split a community, uproot families and generally change the nature of the area.

Changes in the path which the plane uses in approaching and departing the airport are also used to lessen sound levels.[15] By routing the planes over water, undeveloped land or industrial areas, the distances to houses is increased. Unfortunately, this technique depends on such alternatives being available. In addition runways at older airports were positioned before noise problems were considered, so even if there is water or vacant land nearby, it may not be operationally possible to route planes over it because of runway alignments.

Steeper climb-outs may be helpful in some circumstances by getting the plane higher before it crosses inhabited areas. This requires more power for longer periods and is in direct contrast with the power cutback procedures described before. It is most useful where there is a noise-insensitive buffer zone between the airport runway and the community. Northwest Airlines has used such a procedure since jets were introduced into its fleet. The additional fuel consumption is estimated to cost more than $1 million annually.[16]

Steeper landing approaches have the same effect of increasing altitude over listeners. In addition, they actually require less power than normal landing approaches so there is a double noise reduction benefit. In using this technique, the pilot descends on the steeper angle at a faster rate than on the standard approach. Then, at a relatively short distance from the runway, he must slow his descent and adopt the standard approach angle for which the plane has been designed. NASA experiments have shown that this is quite possible, but suggest that further instrumentation and landing aids would be needed both on board the plane and on the ground before this technique would be safe enough for use under all weather conditions, as the increased rate of descent and the transition maneuver greatly amplify the danger from pilot error or equipment failure during the crucial seconds prior to landing.(17)

<u>Dissipation Through Sound-Proofing</u> -- Depending on construction techniques and whether windows are open or closed, the sound levels inside an average home may seem only 1/4 to 1/8 of what they seem outside. Through the installation of storm windows and insulation materials, this number may be halved again. However, even the resulting noise level may be intolerable when the resident is attempting to sleep or concentrate since a close jet overflight would still seem about four times louder than what are considered acceptable indoor noise levels.

In new buildings, various acoustic treatments, designs and materials can further improve the sound damping. However, the cost to halve the noise level again would be an additional ten percent for air-conditioning since the windows would have to be sealed.[18]

Although these techniques could be justified for industrial or commercial buildings where airport access could be a valuable asset that would offset the cost increase, it is doubtful whether they would make sense for residences both because of the costs and because they would not lessen the noise in yards or outdoor areas around the house.

Reduction of Reception/Reaction

Once the sound has been transmitted, there is not much that can be done to reduce its loudness or pitch. Ear plugs or acoustic earmuffs (which could also be considered as devices which block transmission) might be used in industrial areas to protect workers, but would hardly find wide-spread acceptance in commercial or residential settings.

The use of background music or constant noise levels has also been shown to reduce the awareness of single noise events.[19] These techniques might be useful in situations where the peak noise was not excessively above the general background level. By raising the background levels, the peaks do not stand out as much and are less distracting. However, this technique would be worthless where the increased background level itself would interfere with speech or other activities taking place.

In addition to loudness and pitch, the number of sounds and their timing influence negative reactions. As stated by a leading acoustical consultant,

> It is generally agreed that amplitude, frequency content [tone], and time history [duration] of the noise should be considered in [computing] noise exposure. In addition, certain other factors, empirically derived from assessments of community response, are often included in the computation. For example, noise exposure at night is considered more serious than during the day, and an allowance for this is included in the computation....Finally, the time period of activity considered in the analysis, i.e., hourly, daily, monthly, or annual average must be specified.(20)

Since many flights are more annoying than a few and night flights more annoying than those during the day, it is common for the number of noise complaints to increase the longer a given approach or departure path is used or when it is used late into the night. When the path is changed, the complaints drop rapidly--only to start up along the new route.

After the relationship between the number and times of flights and the number of noise complaints received was recognized, various operational changes were instituted to minimize complaints by local residents.

The oldest procedure is the preferential runway system originally adopted by the Port of New York Authority in 1952. Within weather and traffic constraints, the airport assigns priorities to runways based on the usage of the affected land.(21) During the day, a runway might be used which routed flights over homes instead of schools. At night, the preferences would be reversed. Such systems are designed to cause the least impact to the over-all area. However, those exposed to noise from the runway preferred for over-all minimum impact may actually be subjected to higher noise levels than under some other system. This negative aspect of the preferential runway system has been reported by representatives of both the FAA and the airlines.

> Strict adherence to the preferential runway system could create serious noise problems for those airport neighbors living, or working, under the flight path resulting from the use of the preferred runway. For the benefit of all airport neighbors, it may be better to distribute the noise by using all of the runways permissible for the particular wind direction and velocity. Thus, the inhabitants off the ends of all the runways are affected to a limited degree, rather than the persons off the end of one runway being the recipients of all the aircraft noise generated.(22)

Using the distribution of noise concept, recent experiments have been conducted with a rotating preference system that attempts to spread the noise around rather than concentrating it where it has the least impact. Every so many hours, before the community presently being flown over reaches the saturation point, a change is made routing the noise over a new area. This gives the first area a chance to return to normal and, before the second community gets too upset, a change is made to a third. Preliminary results indicate that this technique is effective in reducing the number of complaints, but it is too soon to say how effective the system may be in reducing long-term community annoyance.(23)

In addition to technically measurable qualities or quantities of sound, negative reactions seem based on other more psychological factors. A recent report has characterized those most annoyed by aircraft noise as follows:

> ...They perceive increased air traffic, are highly fearful of aircraft crashing,... and rank medium to very high in noise susceptibility.(24)

There are no technical solutions to these psychological factors. Indeed, they seem induced by the technological changes that have taken place in air transportation. The importance of evaluating these non-technical emotional factors in a policy assessment was recognized by the National Academy of Engineering, which said

> The appraisal of society's readiness to adjust to technology-induced change must be a part of complete assessments; and one of the major objectives of these assessments should be exposure of the principal non-technical obstacles to a constructive use of technology by society. In certain cases, the assessment may find a technology to be fully developed and available, but lack of public appreciation of its potential benefits prevents its acceptance. In these cases, the preparation of the social framework, through education, to accept constructive technological change should be given priority attention if technology is to make its maximum contribution.(25)

Although engineering techniques can reduce sound generation, transmission or reception, problems of community reaction can only be attacked by using technology in its broadest sense.

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V. TRADITIONAL JUDICIAL APPROACHES AND THEIR LIMITATIONS

The imbalance between the private and public costs of aircraft noise and the resulting adverse community relations are as much a result of inadequacies in the judicial system as of the technical problems of noise reduction or the economic problems of computing and allocating costs.(1) If there is no legal liability for damages, the person making the noise need not anticipate the costs of those damages or preventive technology in his own cost/benefit analysis. They remain "external" to his calculations.(2) If liability is imposed by the judicial system, the anticipated costs become a part of doing business and are included in assessing the value of the damage-producing activity to the individual or firm. Thus a particular technology may be accepted as feasible or rejected as too costly depending on what legal rights and remedies exist.

To date, the courts have rarely imposed liability for aircraft noise damage or granted any other effective relief, although many parties have brought suit to stop or collect damages resulting from noisy aircraft operations. In general, parties resorting to the courts can be grouped into four categories:

1. private parties who are directly exposed to the noise and seek to protect their own interests, either individually or through local associations or class actions;

2. environmental groups who are not directly impacted in the traditional sense, but who seek to protect the interests of the public in general in a better environment;
3. local governments who seek to protect the interests of all their citizens; and
4. airport owners and operators who attempt to regulate the actions of those using the facility.

The Rights of the Individual

Through the years, the owner of the property subjected to noise has been the most common litigant. Since class actions and the wide-spread impact of jet noise are relatively recent occurrences, the early cases were primarily individual suits between the property owner and the airport or airplane operator. Most of these actions have been based on three different legal theories.

Trespass -- Trespass actions are based on an actual unprivileged and unpermitted physical invasion of the property of the party bringing the suit.(3) But is a flight through the airspace above a person's land such an invasion?

There are early precedents for granting relief in trespass for invasions of the airspace by projectiles.(4) In these cases, however, invasion was not very high off the ground. With the coming of the airplane, the concept of ownership of the airspace above the land had to be limited if the use of the airplane was not to be stifled by constant litigation arising from overflights.

Therefore, Congress and state legislatures passed acts that placed the airspace above certain minimum altitudes in the public domain and open to the passage of all.(5) However, some courts continued to recognize a "technical trespass" for flights below the pre-empted minimum, unless of an emergency nature,(6) and awarded at least nominal damages. In a very few cases, injunctive relief was actually granted against the operator of the plane.(7)

Nuisance -- In contrast to trespass, a nuisance may arise when an activity unreasonably interferes with the use and enjoyment of the property of another without a physical invasion.(8) Nuisances are usually classified into two types -- the private nuisance affecting a limited number of parties(9) and the public nuisance which has wide-spread effects on the health or welfare of the public in general.(10) Since the latter is a public wrong, it can only be redressed by government action. In these cases, private parties cannot bring an action in their own right unless they can show some special damage not suffered by the public as a whole.(11) As stated in a recent treatise on equity,

> ...Suits to enjoin public nuisances ordinarily are provided by statute to be brought by the state attorney general or other designated officer in the name of the state or the people of the state. Usually the suit may not be brought by and in the name of individuals....(12)

In addition, public enforcement could be difficult when the local government who should bring the action also operates the activity being challenged, as is often the case with airports.

The court could award damages for loss of value, an injunction to stop the offensive conduct or both. However, injunctive relief will not be granted where the harm to one party is outweighed by the benefit to the other or to the public in general. As found by the United States Supreme Court,

> ...Where substantial redress can be afforded by the payment of money and the issuance of an injunction would subject the defendant to grossly disproportionate hardship, equitable relief may be denied although the nuisance is indisputable.(13)

An activity vital to the public good may even become a "legalized" nuisance, particularly if operated under governmental charter or authority. In this case, damages arising from its operation are considered incidental to the public benefit conferred and compensation need not be paid unless negligence is shown.(14) On this theory, the U. S. Supreme Court has denied injunctive relief or damages arising from the non-negligent operation of a railroad, although the adjacent property was affected by noise, vibration and smoke.(15)

As a result, there has been only limited success in blocking new airports by injunctions based on nuisance(16) and recovery from an operating facility on this theory has been very rare.(17) (A recent decision by the California Supreme Court may indicate that this policy will be reexamined for airports, at least in that state.)(18)

Inverse Condemnation -- Most airport operators, as branches of the local government, have the power of eminent domain. Therefore, as long as just compensation is paid, they can take land needed for the public good even if the owner does not wish to sell. On the other hand, a property owner who thinks his land has been taken without compensation can bring an action of inverse condemnation to force payment for what he has lost.[19]

This theory has had wide-spread acceptance since the Supreme Court decision in The United States v. Causby.[20] Causby lived just beyond the end of an airbase runway where bombers repeatedly came over his land at less than 100 feet. As a result, some of his chickens flew into a wall and were virtually scared to death. The Court was able to distinguish Causby from the legalized nuisance cases by finding an actual invasion of the property of the plaintiff.[21] Although the right of the public to free passage in the upper air space without liability was recognized by the Court, flights over private land which are so low and frequent as to interfere with the enjoyment and use of the property were held to be as much an appropriation of property as a conventional entry.

> ...The air is a public highway, as Congress has declared. Were that not true, every transcontinental flight would subject the operator to countless trespass suits. Common sense revolts at the idea. To recognize such private claims to the airspace would clog these highways, seriously interfere with their control and development in the public interest, and transfer into private ownership that to which only the public has a just claim.[22]

> ...We have said that the airspace is a public highway. Yet it is obvious that if the landowner is to have full enjoyment of the land, he must have exclusive control of the immediate reaches of the enveloping atmosphere.(23)

Therefore, the Court held that the passage of aircraft through the airspace, although not normally a basis for recovery, could amount to the taking of an easement under certain circumstances.

> ...Flights over private land are not a taking, unless they are so low and so frequent as to be a direct and immediate interference with the enjoyment and use of the land. We need not speculate on that phase of the present case. For the findings of the Court of Claims plainly established that there was a diminution in value of the property and that the frequent, low-level flights were the direct and immediate cause. We agree with the Court of Claims that a servitude has been imposed upon the land.(24)

Damages were awarded on this basis, although the causes of the injury were the types of wrongs usually associated with nuisance or trespass actions. As the Court said,

> ...The noise is startling. And at night the glare from the planes brightly lights up the place....Respondents are frequently deprived of their sleep and the family has become nervous and frightened.(25)
> ...We think that the landowner, as an incident to his ownership, has a claim to the airspace and that invasions of it are in the same category as invasions of the surface.(26)

Although this reasoning did justify compensating Mr. Causby for an obvious inequity, it had an important undesirable side effect. Since the recovery was based on the taking of property, the compensation has been restricted to those cases where there is an actual invasion of the airspace above the land, so a property owner whose land is not beneath the flight path cannot collect compensation even if the impact of the noise and vibration is severe. Without an overflight, the owner must be deprived of all or most of his interests before compensation is required.(27) Thus, in a case where the damages resulted from the use of an engine test pad at the airport and not from an overflight, it was stated

> ...It is my opinion, as a matter of law from the evidence presented, that plaintiff has not been deprived of "all or most of her interests" in the subject property, so as to constitute a "taking", although there was, indeed, a substantial interference with the use and enjoyment thereof...(28)

This leads to the inequitable result that a person living close to the runway, but to the side, cannot collect for noise damage, while a person who lives further from the airport and experiences less noise may recover if he is "fortunate" enough to have even a small portion of his land beneath the flight path.

Many state courts have been able to avoid this harsh result when the state constitution requires compensation for a "taking <u>or damaging</u>"(29) of property, since a damaging can be caused by the noise and vibration without a physical overflight. However, the federal courts and courts in states without a constitutional requirement to compensate for damages still apply the overflight requirement.(30) Roughly one-half of the states fall in each category.(31)

The Influence of Environmentalist Groups

Although wide-spread recognition of environmental problems is a relatively recent phenomenon, judicial concern can be traced back many years. More than forty years ago Justice Holmes described a river as "more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it."(32) Speaking for the U. S. Supreme Court in 1967, Justice Douglas admonished the Federal Power Commission that the issue is not "whether the project will be beneficial to the licensee....The test is whether the project will be in the public interest...in preserving reaches of wild rivers and wilderness areas...and the protection of wildlife."(33)

But even though the courts have been sensitive to environmental matters, they have not often seen fit to grant standing to individuals or groups that have a general interest in the environmental issues of a case, rather than some direct personal stake in the outcome. As stated by the Supreme Court in the recent case of Sierra Club v. Morton,

> The Sierra Club failed to allege that it or its members would be affected in any of their activities or pastimes....
>
> The Club apparently regarded any allegations of individualized injury as superfluous, on the theory that this was a "public" action involving questions as to the use of natural resources, and that the Club's longstanding concern with and expertise in such matters were sufficient to give it standing as a "representative of the public." This theory reflects a misunderstanding of our cases involving

> so-called "public actions" in the area of administrative law.
> ...The trend of cases...has been towards recognizing that injuries other than economic harm are sufficient to bring a person within the meaning of the statutory language, and towards discarding the notion that an injury that is widely shared is *ipso facto* not an injury sufficient to provide the basis for judicial review.... But broadening the categories of injury that may be alleged in support of standing is a different matter from abandoning the requirement that the party seeking review must have himself suffered an injury.(34)

Although this decision was based on standing, both the majority and dissenting opinions agreed on environmental protection principles that would have been applied if the action were properly brought. For the majority, Justice Stewart declared that

> Aesthetic and environmental well-being, like economic well-being, are important ingredients of the quality of life in our society, and the fact that particular environmental interests are shared by the many rather than the few does not make them less deserving of legal protection through the judicial process.(35)

In his dissent, Justice Blackmun decried the rigidity of law that prevented the Court from reaching issues that involved

> ...significant aspects of a wide, growing and disturbing problem, that is, the Nation's and the world's deteriorating environment with its resulting ecological disturbances.(36)

These statements may indicate that environmental groups will play a larger role in future court actions once technical problems are properly resolved.

The limited success of environmental groups in the courts, however, has not diminished their political importance. The Airport and Airway Development Act of 1970 requires that

> No airport development project involving the location of an airport, an airport runway, or a runway extension may be approved by the Secretary of Transportation unless the public agency sponsoring the project certifies to the Secretary that there has been afforded the opportunity for public hearings for the purpose of considering the economic, social and environmental effects of the airport location and its consistency with the goals and objectives of such urban planning as has been carried out by the community.(37)

As a result, confrontations between airport operators and community environmental groups will occur increasingly more often. In addition, a recent study on community opposition to airport development has identified at least two cases where national conservation groups were able to block new airports through political pressures even after local community organizations had been satisfied with the environmental safeguards proposed.

> Public opposition to the development [of a new Los Angeles airport at Palmdale] rose in three quarters. First there was the dissident local resident who simply did not want to be displaced from his present home, or become an abutter to a giant airport. Other local residents advocated detailed regional planning -- which was endorsed by the local government and the Airport Department. Civic groups organized for economic promotion in the city supported the project completely. They were satisfied that the increased employment and purchasing power of the airport would give rise to great urban development in the region.

> The effective opposition that finally stopped the airport development at this time came from...remote dissident groups. Led by the Sierra Club, the combined conservation groups sought a court injunction in Washington, D. C., to stop the disbursement of Federal funds on the basis of inadequate environmental planning. This action caused much comment in the Palmdale area, for a number of residents felt that the airport complex would be beneficial to the community as a whole. It was also felt that by removing the court case to a distant state, these persons and groups supporting the airport could not afford the expense of appearing in person in the court room and voicing their support. However, from a strategy viewpoint, the Sierra Club, taking this into consideration, made a very effective decision. Because the Department of Transportation, located in Washington, D. C., was being sued, the case could be brought in Washington, D. C....The DOT, seeking to avoid a trial simply temporarily withheld their contributions to the project which, in effect, temporarily halted work on the construction of the airport.(38)

The study also documents a similar problem involving the Florida Everglades.

> ...the originally proposed site had the approval of various government agencies of the State of Florida and the Federal Government. In fact, construction of the facility was well under way with federal airport funds when termination was ordered. [The Dade County Port Authority had] conducted a number of local public hearings and funded a number of research efforts to determine the exact impact of the jetport construction on the Everglades site. Local conservation club branches were satisfied with the site selection process that also included specific input from the Park Superintendent....However, as time progressed, an alliance of the Audubon Society, the Sierra Club and the Friends of the Earth began a lobbying campaign in full force....
>
> As lobbying pressures increased, Secretaries Volpe and Hickel commissioned studies that

> culminated in President Nixon's announcement of the withdrawal of public funds... effectively cancelling the proposed commercial jetport development of the... site.(39)

Thus it can be seen that environmental groups can be powerful political forces and will in all probability become powerful litigants in the future.

Community Restrictions

Federal v. State -- In many cases, the local government has attempted to act for all its citizens by regulating or actually stopping the amount of noise impinging on the community. These attempts are usually based on the power of the local authority to promote and protect the general health, morals and welfare of its citizenry. This power is actually found in the state constitutions. For instance, the constitution of Massachusetts reads "Government is instituted for the common good; for the protection, safety, prosperity and happiness of the people."(40) Acting as an agent of the state government, local governments have traditionally undertaken the regulation of noise through these police powers.

However, under the federal constitution, the states yielded to Congress the "power to regulate Commerce with foreign nations, and among the several states,"(41) while also agreeing in the "Supremacy Clause" that "this Constitution and the Laws of the United States which shall be made in Pursuance thereof...shall be the supreme Law of the land...any thing in the Constitution or Laws of any State to the contrary not withstanding."(42) Thus, when the attempts of the local governments to regulate noise start to impose undue burdens on commerce among the states, a conflict arises between the state and federal spheres of control. Although it is not impossible for both federal and state governments to regulate the same subject matter through powers arising from different sources, federal control is exclusive when a conflict does arise and the area is pre-empted under the Supremacy Clause.

In the 1824 case of Gibbons v. Ogden,(43) the New York legislature had granted exclusive license to Ogden to use steamboats on the Hudson, barring Gibbons from operating between New Jersey and New York although his steamboats had been federally licensed. Arguing vigorously that it had every right to regulate commerce until Congress chose to pre-empt the field, New York insisted that

> ...this power is concurrent; and as such, may be exercised by the states, subject, like all other concurrent powers, to the power of Congress, when actually exercised;...(44)

Supporters of a strong federal government argued that Congress alone could regulate commerce and its failure to act indicated a Congressional policy of no governmental regulation in this area, thereby excluding state action.

> It has been contended by the counsel for the appellant, that, as the word "to regulate" implies in its nature, full power over the thing to be regulated, it excludes necessarily, the action of all others that would perform the same operation on the same thing. That regulation is designed for the entire result, applying to those

> parts which remain as they were, as well as to those which are altered. It produces a uniform whole, which is as much disturbed and deranged by changing what the regulating power designs to leave untouched, as that on which it is operated. There is great force in this argument, and the court is not satisfied that it has been refuted.(45)

The Court neither approved nor disapproved these arguments but found that Congress had in fact pre-empted the area by imposing the federal license requirements which Gibbons had met. Since Congress had acted, New York did not have the power to regulate Gibbons' actions.

> ...all inquiry into this subject seems to the court to be put completely at rest, by the act already mentioned, entitled, "an act for the enrolling and licensing of steamboats"....This act demonstrates the opinion of Congress, that steamboats may be enrolled and licensed, in common with vessels using sails....The one element [steam] may be as legitimately used as the other [sails],...and the act of a state inhibiting the use of either, to any vessel having a license under the act of Congress, comes, we think, in direct collision with that act.(46)

Neither the New York nor the federal positions have ever been specifically accepted or rejected by the Court. The general guidelines that emerged during the first half of the 19th Century (and still basically apply) are:

1. The states, in regulating the general public good, can pass laws which affect commerce, as long as they do not come into conflict with the federal powers. In 1829, the Court held that

> Measures calculated to produce these objectives [to enhance property value and health of inhabitants], provided they do not come into collision with the powers of the general government, are undoubtedly within those which are reserved to the states. But the measure authorized by this act stops a navigable creek, ...But this abridgement, unless it comes in conflict with the constitution or a law of the United States, is an affair between the government of Delaware and its citizens, of which this court can take no cognisance.(47)

2. If the subject matter is by its nature national, or suited to only one uniform system of control, it requires exclusive regulation by Congress. In 1851, it was found that

> Whatever subjects of this power are in their nature national, or admit only of one uniform system, or plan of regulation, may justly be said to be of such a nature as to require exclusive legislation by Congress.(48)

3. Local government can exercise powers that are local and not national in scope in areas where local peculiarities can best be regulated by local legislation until Congress finds it necessary to act.(49)

The Court expressly limited these rules to the cases before it and refused to say they would be valid in all commerce clause situations. However, these rules do provide a background for understanding court reactions to community attempts to regulate noise.

Local Regulation -- In 1956, Cedarhurst, N.Y., attempted to bar overflights below a certain altitude by planes taking off and landing from what is now Kennedy Airport. This was held unconstitutional since the federal government had assumed exclusive control of the airways, preventing the local government from restricting their use.[50]

In a 1968 case involving Hempstead, N.Y., the Court held that local noise ordinances normally within the police power of the town were unconstitutional since planes had to deviate from the federally-established flight paths to comply. Since every other town around New York's Kennedy Airport was about to pass similar ordinances if Hempstead's were upheld, there would be no way for planes to divert. The resulting constraints on the flight paths in and out of the airport would limit operations as severely as Cedarhurst's altitude regulations and, therefore, these ordinances were also unconstitutional.[51]

Communities have also attempted to impose curfews on nearby airports. In 1969, the California courts upheld the right of a city to prohibit night jet flights in Stagg v. City of Santa Monica,[52] since no interference with the federal power was found. Citing from an earlier case, the Court said

> Moreover, we note that noise abatement is a federal as well as a state aim and when not inconsistent with safety...would not necessarily present a conflict with federal law but might well reinforce it.[53]

However, there was no commercial aviation at this airport and the city was its owner and operator. The Court felt that, under the public utility code,

> ...the operation of a municipally owned airport...has been expressly committed by statute to the local agency. Government Code,...Section 50474...provides:

> In connection with the erection or maintenance of...airports or facilities, a local agency may...(f) Regulate the use of the airport and facilities and other property or means of transportation within or over the airport....(54)

It is not clear whether both of these factors must be present for local control to be upheld. However, when the city of Burbank, California, passed a similar regulation based on the Santa Monica case, it was struck down as an unconstitutional interference with interstate commerce.(55) Here neither factor was present, since there was interstate commercial aviation and the terminal was neither owned nor operated by Burbank.

The trial court in the Burbank case stressed the national nature of the air system and found that the federal government has so completely occupied the area of airspace control that Congress left no room for local regulations of the type Burbank sought to enforce.

> ...if the time during which the navigable air space may be used is to be curtailed, the Court concludes that the action must come from Congress, or its authorized agency, if the safe and efficient use of the air space is to be maintained and interstate commerce protected from unreasonable burden and interference.(56)

The trial court held further that, if the Burbank regulation were upheld, all cities would soon pass curfews causing a cascade effect severely limiting the movement of air mail and air cargo, which would ultimately place an undue burden on interstate commerce. In the words of the Court,

> The noise problem created by jet aircraft is well known and it appears to the Court that a curfew ordinance, if valid, would promptly be adopted by virtually all cities surrounding airports. Considered singly, such an ordinance might not impose an unlawful interference with interstate commerce. However, considered on a national level, the ordinance could not stand.(57)

On review, the Court of Appeals for the 9th Circuit held

> The pervasiveness of federal regulation in the field of air commerce, the intensity of the national interest in this regulation, and the nature of air commerce itself require the conclusion that state and local regulation in that area has been preempted.... Furthermore, the Federal Aviation Act also contains language of exclusivity. 49 U.S.C. §1508 [(1970)] declares that the United States possesses and exercises "complete and national sovereignty in the airspace of the United States...." That is the same type of expression which the Supreme Court found in the Federal Tobacco Inspection Act to evidence Congressional intent to establish a wholly federal system which states were powerless even to surplant.(58)

<u>Zoning Restrictions</u> -- Local governments have used their zoning powers to impose land use restrictions around the airport. However, the zoning power can only be used to place minor restrictions on land use that will benefit the public good, health and general welfare while still not placing an undue burden on the land owner. As stated by the U. S. Supreme Court,

> The governmental power to interfere by zoning regulations with the general rights of the landowner by restricting the character of his use, is not unlimited, and other questions aside, such restriction cannot be imposed if it does not bear a substantial relation to the public health, safety, morals, or general welfare.(59)

The courts distinguish between minor restrictions that limit enjoyment and use and those that amount to an appropriation of property for public use, stating that "...the city may not under the guise of an ordinance acquire rights in private property which it may only acquire by purchase or by the exercise of its power of eminent domain...."[60]

In 1963, an Indiana court held that an attempt to zone land near an airport to prohibit structures over the height that would not interfere with the glide slope was more than a minor restriction and amounted to a taking of the airspace which required compensation.[61] It is arguable that a zoning scheme based solely on noise considerations is really a taking of aviation easements and just compensation would be required. Thus, the airport and city planner must be very careful how the zoning ordinances are drawn.

In addition, zoning cannot be used to bar an activity already in existence.[62] Therefore, the Indiana court felt that any attempt to change the nature of use around present airports could only be done through condemnation proceedings where full compensation would be paid, saying

> ...regulation under the police power which can be modified at the discretion of the regulating authority is wholly different from the taking or appropriating of private property by the government for a specific use. The latter can be effected only if compensation is provided....With this distinction established, it becomes apparent that the City of Gary has attempted, by the passage of the ordinance under consideration, to take and appropriate to its own use the

> ordinary usable air space of property adjacent to the Gary Airport without the payment of compensation.[63]

Rights of the Airport Operator

Anticipating the coming jet age and its associated noise problems, the Port of New York Authority (PONYA) was the first airport operator to set noise standards for aircraft using its facility. As explained by the Port Authority's chief acoustics consultant,

> ...we decided that the operation of jet aircraft could only be approved at our airports after a showing that the noise under the take-off would be comparable with, and certainly not greater than, that of the large four-engine piston transports then in use. In the early days of transport jet development, we refused permission to both Boeing and deHavilland to bring jet transports to New York because of noise problems.[64]

The Port Authority relies on its position of landlord to enforce its rules and regulations. PONYA requires jet aircraft to obtain permission in advance to use its airports and that permission is contingent on an agreement to comply with the rules and regulations.[65] In addition, all airline leases contain a clause specifically stipulating that the carriers must comply with all these rules and regulations as a condition of their tenancy.

The aircraft noise standards of the Authority have never been directly challenged, but the general powers of PONYA to impose restrictions on the use of its facilities have been tested in two instances.

The first involved the use of a particular runway at La Guardia airport. The Port Authority had a rule in force stating that the runway in question could only be used if a given noise level was not exceeded in nearby communities. The airlines complied with this rule for two years while extensions were being made to allow safer jet operations on that runway. When the work was completed, the airlines started operations and challenged the restriction on the basis that it was unreasonable and an interference with federal regulations which pre-empted the field. The Port Authority sought to enjoin the airlines from violating their agreements.(66)

The Court upheld the Port Authority and found no conflict with federal regulation. The Federal Aviation Agency in operating the tower had never directed anyone to use the questioned runway even though it was available for use under particular weather conditions. Also, an additional runway which was to be operational within seven weeks would alleviate the problem. At most, only nine percent of the operations were affected, and other airports were available as alternatives. Since noise was a major problem, these restrictions did not appear excessive. The Court held that

> By reason of its specialized experience and expertise, the Port Authority is uniquely equipped to weight the various conflicting interests and to resolve the same by the adoption of regulations which it believes to be reasonable. In so doing its judgement is not affected by any special or personal interest. It is not for the Court to substitute its judgement for that of the Port Authority or decide what regulations should be adopted. Its function is only to determine

> in the light of all the circumstances whether the particular regulation is so unreasonable as to violate the understanding between the parties....[The Court] is convinced that under the circumstances the regulations...are still reasonable....(67)

In the second case, the Aircraft Owners and Pilots Association (AOPA), which represents general aviation interests, challenged the Port of New York Authority's right to charge a landing fee that had the intent and effect of forcing private pilots to use other airports, allowing more commercial operations at the three major New York airports during periods of congestion.(68) AOPA contended that this amounted to a restriction on air traffic and thus was local regulation of a federally pre-empted field.

Again, the Court found no conflict between the Port Authority's acts and federal regulations; instead, both worked together to alleviate the severe peak-hour congestion being experienced at the New York facilities. The Court stated

> Nothing in the present fee schedule runs counter to the FAA regulation in the sense that it seeks to authorize conduct which the federal regulation prohibits or requires the cessation of a practice required by federal regulation....United in general purpose with the high density regulation [imposed by the FAA], the revised fee schedule, if viewed as a regulation of air traffic, simply has the tendency further to restrict the traffic restricted by the federal regulation, but to do so in a direction of restriction and for an aim common to both sets of regulation.(69)

These two cases, plus Stagg v. Santa Monica mentioned earlier, have been cited as authority for the general proposal that the airport operator can regulate the noise levels at his airport. However, all three cases are actually quite limited by their particular facts and may not justify so broad a conclusion.

In each case, the Court found no interference with federal authority, thus ending the inquiry. However, since most commercial airports in the United States are owned and operated by local or state governmental agencies, it can be argued that their rules and regulations are but another form of local ordinance and consequently subject to the same constitutional conflicts. It is therefore probable that the airport proprietor's regulations would fall if at some point they did conflict with federal law.

All that can safely be said is that the operator of the airport can impose some limits on operations through his contracts with the users as long as the restrictions are reasonable, do not place an undue burden on interstate commerce, and do not conflict with some federal rule or regulation.

The ability of the airport operator to somewhat control the noise of his facility is important, since he is responsible for any resulting damage. In the case of Griggs v. Allegheny County,(70) the Supreme Court of the United States held that the airport operator, "as promotor, owner, and lessor of the airport",(71) was the one who had to take the required easements for flight paths since the operator decided "where the airport would be built, what runways it would need, their direction and length, and what land and navigation easements would be needed."(72) The federal government merely approves the plans, and the airplanes fly where directed. This places the burden of paying for navigation easements on the airport operator. Therefore, it is important that he be able to regulate the noise levels and, to some extent, limit his liability.

Summary

Any technological or policy change proposed to alleviate the airport noise problem should not rely on traditional modes of enforcement since the judicial solutions to date have been largely unsuccessful. Although there have been cases where an individual recovered for the diminution of value of his property due to noise and vibration, the property owner's rights are limited in the federal and in many state jurisdictions to cases of direct overflight above the property.

Environmental groups have not had much success in the courts either. However, they promise to be an increasingly effective litigant in the future as technicalities regarding their standing to bring actions are clarified. In the interim, these groups continue to exert effective political pressure in many matters.

Efforts by the community to control noise have been struck down except when the local government unit was also the operator of the facility. In general, the courts have upheld the airport operator's rights to impose noise restrictions through contracts with the airlines, so, as a class, the operators of airports have been most successful in imposing noise limits. However, since the operator's financial well-being depends on expanding air commerce, the noise restrictions may not have been as severe as those recommended by community groups.

These limitations of the traditional judicial system must be considered when applying policy assessment methods to proposed airport noise solutions.

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30. Town of East Haven v. Eastern Airlines, Inc., 331 F.Supp. 16 (D.C. Conn. 1971); Avery v. United States, 330 F.2d 640 (Ct. Cl. 1964); Aaron v. United States, 311 F.2d 798 (Ct. Cl. 1963); Ferguson v. Keene, 108 N.H. 409, 238 A.2d (1968); Bowling Green-Warren County Airport Board v. Long, Ky., 364 S.W.2d 167 (1962).

31. Anon. Noise Litigation Study. Oregon State Highway Department (1965), p. 12.

32. New Jersey v. New York, 283 U.S. 336, 342 (1931).

33. Udall v. Federal Power Commission, 387 U.S. 428, 450 (1967).

34. Sierra Club v. Morton, 405 U.S. ______, 92 S.Ct. 1361, 1366-1368 (1972).

35. Id., p. 1366.

36. Id., p. 1376.

37. 49 U.S.C. 1716 (d) (i).

38. Lantner, G. H. Community Opposition to Airport Development. Massachusetts Institute of Technology, Civil Engineering Department Report R72-1 (1972), p. 108-111.

39. Id., p. 72-76.

40. Massachusetts Constitution, Part I, Article 7.

41. United States Constitution, Article I, Section 8.

42. Id., Article VI.

43. Gibbons v. Ogden, 9 Wheat. 1 (1824).

44. Id., p. 64.

45. Id., p. 209.

46. Id., p. 220.

47. Willson v. Black Bird Creek Marsh Co., 2 Pet. 245, 250 (1829). See also Munn v. Illinois, 94 U.S. 113 (1877).

48. Cooley v. Board of Wardens of Port of Philadelphia, 12 How. 299, 319 (1851). See also Wabash, &c. Railway Co. v. Illinois, 118 U.S. 557 (1886).

49. Id., Cooley.

50. Allegheny Airlines v. Village of Cedarhurst, 238 F.2d 812 (2d Cir. 1956).

51. American Airlines, Inc. v. Town of Hempstead, 272 F.Supp. 226 (E.D.N.Y. 1967), aff'd., 398 F.2d 369 (2d Cir. 1968), cert. den., 393 U.S. 1017 (1969).

52. Stagg v. Municipal Court of Santa Monica, 82 Cal. Rptr. 578 (1969).

53. Loma Portal Civil Club v. American Airlines, Inc., 61 Cal.2d 582, 592 (1964).

54. Stagg. Supra, reference 52, p. 581.

55. Lockheed Air Terminal, Inc. v. The City of Burbank, 318 F.Supp. 914 (D.C. Cal. 1970), Aff'd. 457 F.2d 667 (9th Cir. 1972), cert. granted, U.S.L.W. 3165 (Oct. 11, 1972).

56. Id., 318 F.Supp. 914, 930.

57. Id., p. 927.

58. Id., 457 F.2d 667, 671-675.

59. Nectow v. City of Cambridge, 277 U.S. 183, 188 (1928).

60. Yara Engineering Corp. v. City of Newark, 132 N.J.L. 370, 373, 40 A.2d 559, 561 (1945).

61. Indiana Toll Road v. Jankovich, 193 N.E.2d 237 (1963), cert. granted, 377 U.S. 942 (1964), cert. dismissed as improvidently granted, 379 U.S. 487 (1965). Contra see Baggett v. City of Montgomery, 276 Ala. 166, 160 So.2d 6 (1963).

62. O'Reilly, Jr. The Non-Conforming Use and Due Process of Law. 23 Geo. L. J. 218 (1935).

63. Indiana Toll Road. Supra, reference 61, p. 241.

64. Odell, Albert H. Jet Noise at John F. Kennedy International Airport. Port of New York Authority (1966).

65. The New York Port Authority: Rules and Regulations for Air Terminals. Rule 2, Section I; Rule 15, Section II. (Revised April 1, 1966).

66. Port of New York Authority v. Eastern Air Lines, Inc., 259 F.Supp. 745, 748 (1966).

67. Id., p. 751.

68. Aircraft Owners and Pilots Association v. Port Authority of New York, 305 F.Supp. 93 (1969).

69. Id., p. 105.

70. Griggs v. Allegheny County, 369 U.S. 84 (1962).

71. Id., p. 89.

72. Id., p. 89.

VI. LEGISLATION AND ITS LIMITATIONS

Solutions to the airport noise problem that do not directly involve the airport operator, the airlines or the aircraft and lie totally outside the scope of traditional technology must also be examined. These are legislative solutions developed as local, state and federal governments consider the rights of the citizens near the airport relative to the over-all benefits of air service to the area and nation as a whole.

Depending on the location of the airport, several independent jurisdictions may be involved. It has been estimated that on a clear day 1300 separate political jurisdictions can be seen from the top of the Empire State Building.(1) Effective coordinated action in such cases is all but impossible.

Local Legislation

Since local governments are restricted by constitutional conflicts with federal powers over interstate commerce, they must look for methods of airport regulation through techniques of land use and transportation planning backed by their police powers to protect the general health and welfare of the citizenry.

Alternate Services -- Communities could limit or actually replace air service with other modes of transportation such as improved rail (including advanced air-cushion devices) or highways.(2) But these solutions might lead to the same or additional problems.

First, neither rail nor highways are free from noise. Airports create islands of noise in their immediate vicinity but with relatively little noise impact on outlying areas. Highways and tracked vehicles create alleys of noise along their entire length. Where rights-of-way already exist, this effect has probably been discounted over the years. However, where new rights-of-way are needed either to put in new services or improve present service (i.e., by straightening curves), new noise impact areas are created. In fact, for distances greater than 100 miles, the land area severely affected by noise for a city-to-city rail system exceeds that of the airports at both ends (which are also used by service from all cities connected to the original pair).(3)

Second, the costs of acquiring the land and constructing new highways or rail systems are prohibitive in all but very high-density corridors, because so many passengers must be carried to offset these high fixed costs. In addition, population centers in these corridors must be stable, since ground systems cannot easily be shifted to follow new growth patterns. By contrast, the initial investment in air facilities is relatively low. The major investment is in vehicles which are purchased only in proportion to the number of passengers in the market. This, coupled with the airplane's relative freedom from ground restraints, results in a system which is both cheaper and more flexible in all but the most dense markets where the costs of a large number of vehicles could exceed ground right-of-way costs for the other modes. (The trade-off between rail and air systems is shown in Figure VI-1.)

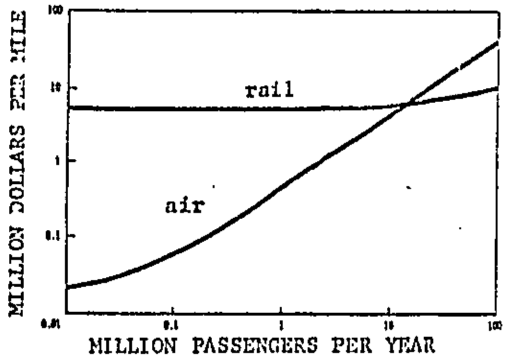

Fig. VI-1 Investment per Mile -- Rail and Air Systems[4]

Third, a ground system can never match the speed of aircraft on long-range service, nor could it provide any transoceanic alternative. Thus, there will always be air service between the major cities of this country and of the world and air service could be totally eliminated only between smaller cities or between small cities and major hubs. However, it is in these lower density markets that the air system has its greatest economic advantage and flexibility.

> ...the investment per route mile for air systems is proportional to traffic volume along a route since vehicles are added as the system proves its need. For low volume routes (less than 100,000 passengers per year), there is an investment ratio of roughly 100:1, and it is not until there are 10 million passengers per year on a route that the investment per mile in the air system equals that of the ground system. Conversely, for low volume routes, the same investment would provide about 100 times the route mileage for the system. It is not surprising to notice that when governments wish to provide transportation to open up new areas of their country (as

in Canada, Australia, Africa or Russia), they no longer invest in rail systems.(5)

Finally, transportation systems are no longer local in nature. Although a small city might decide to close its airport, it cannot by itself obtain the rights-of-way needed to connect with a distant hub by rail or highway. This can only be done by cooperation between many governmental units with a common goal.

<u>Relocation</u> -- Many cities have closed down their older in-city airports and built new facilities in less populated areas. This has usually been motivated by a need for more room and increased capacity rather than as a noise reduction technique. Although some regions have been successful in acquiring new sites (Dallas-Fort Worth), most have been blocked by local residents in the selected area (New York). The only successful acquisitions have been new airports located many miles from the downtown hub that generates much of the traffic (Montreal). Even in cases where a new airport has been opened, the old one often has not been permanently closed as originally planned (Chicago Midway). As pressures for increased services have grown both airports have been needed to meet the demand. However, a new airport does divert a large portion of the city's service to the remote location providing limited noise relief, particularly from the larger aircraft used in long-distance flights. An example of this can be seen in the Washington, D. C., area where long haul flights were transferred to Dulles and Friendship

Airports, and service at Washington National was restricted to flights of less than 650 miles.(6)

Renovation -- Often it is cheaper for a city to renovate its present facilities than relocate them, particularly where there is sufficient land area available or easily obtainable to meet service and runway requirements. Additional land can be obtained by harbor fills or limited condemnations. This is the case in Boston. Neighborhood objection is bound to increase, however, since more aircraft will use the expanded facilities and there still is not enough land to allow dissipation of the noise before it reaches residential areas.

Limitations and Curfews -- In addition to the technical constraints of runway capacity and the air traffic control system, attempts have been made to impose artificial constraints on the type of aircraft that can use a facility, the number of operations permitted and the time of these operations. However, these types of constraints have not been upheld by the courts unless imposed directly by the owner or operator of the airport.

The impact of limitations or curfews goes much further than noise reduction in the vicinity of the airport. Limitations on the type of aircraft can effectively eliminate long-distance flights which require large planes. Therefore, such limitations can be imposed only where there is another airport available that does not have such restrictions. This results in additional noise at that second airport when flights are transferred from the first.

A limitation on the number of flights in and out of one airport has a direct impact on the airports at the other end of those flights--even if they have no noise problem. When the limitations become total as during a night-time curfew and when several major airports impose similar rules, the effect on the air system is magnified since time zone changes and the time spent in the air limit the number of arrival and departure alternatives.

The potential accumulative effects have not gone unnoticed by the courts. In a recent case, the Court considered the effects that an 11:00 p.m. to 7:00 a.m. curfew would have if imposed nationally.

> ...The Ordinance on a national basis would increase costs by 25%...by reason of the loss in the utilization of aircraft as well as the required purchase of new planes to meet the concentration of flights within the permitted hours of take-off, if, in fact, the rescheduling of flights so eliminated could be accomplished from a practical standpoint. Additional maintenance shops would also have to be established by all airlines to accomplish the required maintenance at necessary locations for proper and efficient use of their planes.(7)

Detailed analysis, however, indicates that the impact would be considerably less than indicated (see Section VII).

Zoning--Although there are legal restrictions on the use of zoning around an airport, it can be a powerful tool when properly applied to assure land use that is compatible with airport noise. Forty-two states have adopted express enabling legislation providing for airport zoning. It has been estimated that there are more than 500 airport zoning ordinances of one type or another currently in effect in the United States.(8) Under these plans, noise-sensitive areas such as residences, schools and hospitals are prohibited, while manufacturing and recreation areas are encouraged. This technique is most helpful when used in conjunction with new airport development, but has little application around older airports since property uses in being cannot be zoned away.(9)

To be effective, zoning must be done on a regional basis, since the noise usually affects many surrounding communities in addition to the political unit in which the airport is located. It should also be coupled with stringent building codes that minimize noise inside structures by requiring sound-proofing where needed.

The limitations of local governments in dealing with environmental problems in general has been recognized by the Council on Environmental Quality which stated in its second annual report:

> The traditional local zoning system is ill-suited to protect broader regional, state and national values. Local governments have a limited perspective on and little incentive to protect scenic or ecologically vital areas located partially or even entirely within their borders. Economic pressures often spur development to the detriment of the environment because of local government dependence on property taxes.
>
> Local land use regulation alone, therefore, cannot deal efficiently with many of today's environmental problems: protecting lands that have natural or esthetic value

> to a region; accomodating development that is necessary for a region but may not be desired by local communities; and controlling large-scale development that impacts upon more than one local government. Recent state initiatives in land use regulation are aimed at overcoming these disabilities.[10]

<u>State Legislation</u>

Several states have either proposed or enacted measures to control airport noise. Under the Minnesota Airport Zoning Act, the State Airport Commission was given the power to determine guidelines for zoning and comprehensive land use planning around airports in the state. Local governments must get the approval of the State Commission before local land-use regulations can be imposed.[11]

The state of California has adopted a unique plan for the regulation of airport noise throughout the state, which, if upheld by the courts, will serve as a model for other states.[12] The plan stresses noise impact reduction by all means rather than by noise limits alone. Although absolute noise levels are set for individual aircraft operations, they are not essential for the operation of the plan. Instead, the limits are set to protect individuals from being exposed to harmful noise levels rather than to control airport noise.

Individual noise constraints are enforced at two levels. Under the regulations:

> No operator of an aircraft shall operate any aircraft in excess of the single event noise exposure level limits adopted.[13]

Violations are a misdemeanor and subject to a substantial fine unless

> ...such operation is the direct result of the pilot's exercise of his responsibility for the safety of the passengers, crew, cargo and aircraft or of his emergency authority.[14]

In addition to the operator of the aircraft, the operator of the airport is held liable for violations of the single event limits.

> No airport proprietor shall knowingly permit any aircraft operator to exceed the single event noise exposure level limits...[15]

Although this approach to controlling individual noise events is in itself unusual, the unique feature of the California plan is in the section stating

> No airport proprietor shall operate his airport with a noise impact area of other than zero unless said operator has a variance.[16]

This section attempts to regulate noise impact rather than noise alone and gives a flexibility and adaptability that is lacking in most plans.

The noise impact area is based on the amount of land subjected to an average noise level that exceeds the limits established as compatible for the existing type of land use. These limits were developed from numerous studies of the impact of noise on sleep, communication, health and other factors.[17] Different limits are specified for various activities, thus permitting various amounts of noise depending on local conditions.[18]

The average noise level is determined for property near the airport by computing or measuring how loud each aircraft operation is at the point in question and then weighting the result by the time of day when the noise occurred.[19] One flight during the evening relaxation hours is considered to cause as much annoyance as three separate flights during the day, while flights during sleep periods are considered as offensive as ten daytime operations. The impacts of all the noise levels are combined to yield the average daily level.[20] This number is compared to the standard for the property to see if a violation has occurred.

This formulation gives the airport operator the option of using several types or combinations of techniques to reduce noise impact beyond the airport boundary.[21] Either through variable landing fees or contracts with the airlines, the airport proprietor can encourage the use of aircraft with lower noise characteristics while discouraging noisier airplanes. By lowering the noise level of each operation, the proprietor lowers the average value of noise impact.

The proprietor can also encourage the use of runways, flight paths and operational procedures that reduce the noise or increase the distance between the noise source and the noise impact boundary. Shielding (the use of natural terrain, buildings, etc.) would likewise reduce the noise that reaches the measurement points and thus lower the average levels.

Since evening and nighttime operations are heavily weighted, the proprietor of an airport that has many flights during these noise-sensitive periods can greatly reduce the average noise level for the area by imposing flight restrictions or a curfew. If the airport has 90 flights during the day and 10 at night, the 10 nighttime operations (which are considered ten times as offensive as the day operations) would add more to the average noise impact level than all the day flights combined. Consequently, by eliminating these ten night flights, the proprietor of the airport can substantially reduce the average impact level while decreasing his capacity by only ten percent. Thus reduction of flights, particularly during the noise-sensitive periods by noisier aircraft, is an effective control of over-all noise impact.

Limitations on the number of flights that can operate at an airport have an additional effect on noise reduction that is not immediately obvious. While landing fees proportional to noise levels or fines for excessive noise might encourage airlines to buy quieter planes, the degree of incentive would depend on the policy established by the Civil Aeronautics Board. If all or a portion of the costs could be passed on to the passengers through a fare increase, an airline would carefully weigh the potential savings in noise costs against decreased traffic, the remaining life of the noisy equipment, and similar factors before undertaking a large re-equipment program.

However, frequency limitations cannot be passed on through a fare increase. Since the over-all noise impact for several flights by a quiet aircraft could be the same as for a few flights by noisier planes, the first airline to get quiet planes could fly more often and still meet the same noise criteria. Since the airline with the greater frequency of service between two cities is known to get more than a proportionate share of the passenger traffic, there would be a strong incentive to be the first to fly quieter planes.(22)

Finally, the airport proprietor could reduce the noise level at the noise impact boundary either by expanding the boundary physically or by changing the land use of property to be compatible with the noise impact level. This could be done by actually buying land or by paying for building modifications, purchasing easements and otherwise controlling land use without actual purchase.

In addition to the flexibility that this plan gives to the airport operator, it permits community involvement in the setting of standards. Although the minimum levels of tolerable noise impact are established by the state, the county governments are expected to work with the airport proprietor in setting levels best suited to the area.(23) Thus, if an area felt that economic development would be encouraged by a busy airport, it could decide to impose only the minimum standards required by the state. If, on the other hand, the area wanted some air service but valued quiet more, it could set standards that were higher than the state's and, thus, better suited to its needs.

In addition, it is up to each county to decide how it defines a noise problem and what airports within its jurisdiction have such a problem. The county government may also require the installation of an automatic noise monitoring system at an airport if it feels that the problem requires it.[24] To avoid confusion, the minimum standards and specifications for such a monitoring system are set out in great detail in the state regulations.[25]

In its plan, California has attempted to avoid a violation of the commerce provisions of the federal constitution in several ways. First, the limits set for individual aircraft operations are very close to those imposed by federal regulations, although a different measurement technique is used. Second, the state contends that, based on the legislative history and intent of federal laws, it can act to the extent that it is not prohibited by federal action.[26] For support, California relies on Public Law 90-411 which empowered the Federal Aviation Administration to set noise standards for aircraft. In the history of the act, it is stated that

> The bill is an amendment to a statute describing the powers and duties of the Federal Government with respect to air commerce. As indicated earlier in this report, certain actions by state and local public agencies, such as zoning to assure compatible land use, are a necessary part of the total attack on aircraft noise. In this connection, the question is raised whether this bill adds or subtracts anything from the powers of state or local governments. It is not the intent of the

committee in recommending this legislation to effect any change in the existing apportionment of powers between the Federal and state and local governments.

In this regard, we concur in the following views set forth by the Secretary in his letter to the committee of June 22, 1968:

> The courts have held that the Federal Government presently preempts the field of noise regulation insofar as it involves controlling the flight or aircraft. Local noise control legislation limiting the permissible noise level of all overflying aircraft has recently been struck down because it conflicted with Federal regulation of air traffic. American Airlines v. Town of Hempstead, 272 F.Supp. 226 (U.S.D.C., E.D., N.Y., 1966). The court said, at 231, "The legislation operates in an area committed to Federal care, and noise limiting rules operating as do those of the ordinance must come from a Federal source." H.R. 3400 would merely expand the Federal Government's role in a field already preempted. It would not change this preemption. State and local governments will remain unable to use their police powers to control aircraft noise by regulating the flight of aircraft.
>
> However, the proposed legislation will not affect the rights of a state or local public agency, as the proprietor of an airport, from issuing regulations or establishing requirements as to the permissible level of noise which can be created by aircraft using the airport. Airport owners acting as proprietors can presently deny the use of their airports to aircraft on the basis of noise considerations so long as such exclusion is non-discriminatory.
>
> Just as an airport owner is responsible for deciding how long the runways will be, so is the owner

> responsible for obtaining noise easements necessary to permit the landing and takeoff of the aircraft. The Federal Government is in no position to require an airport to accept service by larger aircraft and, for that purpose, to obtain longer runways. Likewise, the Federal Government is in no position to require an airport to accept service by noisier aircraft, and for that purpose to obtain additional noise easements. The issue is the service desired by the airport owner and the steps it is willing to take to obtain the service. In dealing with this issue, the Federal Government should not substitute its judgement for that of the states or elements of local government who, for the most part, own and operate our Nation's airports. The proposed legislation is not designed to do this and will not prevent airport proprietors from excluding any aircraft on the basis of noise considerations.
>
> Of course, the authority of units of local government to control the effects of aircraft noise through the exercise of land use planning and zoning powers is not diminished by the bill.
>
> Finally, since the flight of aircraft has been preempted by the Federal Government, state and local governments can presently exercise no control over sonic boom. The bill makes no change in this regard.(27)

This position has been enhanced by the passage of Public Law 92-574, The Noise Control Act of 1972, in which several specific references are made to the right of local and state authorities to establish and enforce controls on environmental noise.(28)

Finally, the state relies on those cases upholding the right of the airport proprietor to set noise limits for operators using his facility. The California plan makes the proprietor liable for violations of the noise standards and threatens revocation of his permit for non-compliance.(29) The operator is then the one who imposes the curfew, bans certain aircraft, etc., not the state itself.

A major problem with the California plan is enforcement. If the airport proprietor does not comply, the state may revoke his right to operate the airport. Although this may be an effective threat against a private or small operator, it is doubtful whether such an action could be enforced against the City of Los Angeles or whether any of the major California airports could really be closed.

Another problem is whether the standards set are realistic over the time period proposed. Since present airports do not have to meet the minimum noise levels until 1985,(30) the time problem is not crucial. In addition, the state has shown a willingness to cooperate and grant variances where required. Therefore, it would seem that realistic standards and an appropriate time frame will emerge over the next few years.

Federal Legislation

The two major federal acts passed to date primarily attempt to directly limit the level of noise, rather than concentrate on the elimination of noise impact on the community.

There are two major problems with this type of approach. The first is in the definition of how the noise is to be measured. Technologists do not agree on what qualities of the sound should be considered or what the relative importance of these qualities is. There is debate over what equipment should be selected to make the measurements, where it should be placed and who should operate and control it.

The second problem is where the limits should be set after a measurement technique is adopted. The selection of the maximum sound levels is based on the value judgements of the decision makers as to what is good for the population as a whole and is subject to political pressures. At the local level, the desire to please the voters would cause a tendency to undervalue the national importance of commerce and overvalue community impact. At the national level, organized industry lobbies might bias decisions against community interests since local groups would offer only scattered and divergent viewpoints.

In either case, any law that sets absolute limits on the noise that an aircraft can make is probably inefficient from an economic standpoint. The efficient amount of noise reduction occurs when the cost of further reduction in noise exceeds the benefit that the community receives from a reduction in noise impact. Since the noise impact depends on several factors in addition to the absolute noise level, any plan that deals solely with the noise cannot possibly meet the needs of all communities.

If the noise level is set to alleviate noise impact at some average airport, then it may not be high enough to significantly reduce the problem at high-noise airports. If the noise level is set to alleviate the high-noise problem, then the cost of noise reduction to the air system will be much greater than that needed to reduce noise impact at most airports. In one case, there is too much noise; in the other, too much noise reduction.

Public Law 90-411 -- Under Public Law 90-411,[31] the Federal Aviation Administration was given the authority to prescribe and amend rules and regulations necessary "to afford present and future relief and protection to the public from unnecessary aircraft noise...."[32] In setting these rules and standards, the Administrator of the FAA was to consult with federal, state and interstate authorities as he felt appropriate,[33] consider the impact of such rules and standards on safety,[34] and evaluate their economic and technical reasonableness.[35] This law represented the first major attempt to control commercial aircraft noise at the national level.

Federal Aviation Regulation Part 36,[36] issued in response to the above charge, set standards on the noise levels that could be made by different weight-classes of aircraft during take-off and landing. But it was primarily prospective in operation since aircraft certified before the regulation came into effect were given various exemptions.[37] However, the regulations specifically avoided the question of the resulting impact of noise standards on the community.

> Pursuant to 49 U.S.C. 1431 (b) (4), the noise levels in this part have been determined to be as low as is economically reasonable, technologically practicable, and appropriate to the type of aircraft to which they apply. No determination is made, under this part, that these noise levels are or should be acceptable or unacceptable for operation at, into, or out of, any airport.(38)

Public Law 92-574, the "Noise Control Act of 1972"(39)--
Partially in response to the previous failure to consider noise impact on the local community, Senators John Tunney of California and Edmund Muskie of Maine introduced The Environmental Noise Control Act of 1972 (S. 3342) on March 14, 1972. As stated by Senator Muskie,

> The bill which we introduced was not... designed primarily to relieve transportation companies, particularly the airlines, from effective noise regulations.
> ...To date, regulation of aircraft noise pollution has been the sole responsibility of the Federal Aviation Administration. The Federal Aviation Administration has had this responsibility since its inception. It has had a specific legislative mandate for the past four years. And its record is wholly inadequate.(40)

Although the original bill sought to transfer the determination of aircraft noise standards to the Environmental Protection Agency (EPA), the act as finally passed retains the dominance of the Federal Aviation Administration (FAA). However, it does emphasize growing congressional concern for the public health and welfare. As stated by Senator Tunney on the Senate floor,

> It is not the intention of the Congress that the phrase "economic reasonableness" continue to be interpreted as it has in the past under section 611 of the Federal Aviation Act. By recasting the control of aircraft noise in a new regulatory framework, Congress intends that the reasonableness of the cost of any regulation or standard be judged in relation to the purposes of this act, which is to protect public health and welfare from aircraft noise. Costs are to be judged against that goal, not for their effect on air commerce or particular air carriers.
>
> The key element in this proposal is protection of the public health and welfare. The key element is not, as some may believe, protection of commerce. The Federal Aviation Administration's regulatory responsibility is retained in order to assure technological availability and protect safety. However, the FAA, following the lead of EPA, will be required to promulgate regulations which shall assure protection of public health and welfare in airport environments even where it is not possible to achieve necessary noise reductions through the application of specific emission controls on engines and aircraft.(41)

To carry out these goals, the new law charges the Administrator of the Environmental Protection Agency to

> ...conduct a study of the (1) adequacy of Federal Aviation Administration flight and operational noise controls; (2) adequacy of noise emission standards on new and existing aircraft, together with recommendations on the retrofitting and phaseout of existing aircraft; (3) implications of identifying and achieving levels of cumulative noise exposure around airports; and (4) additional measures available to airport operators and local governments to control aircraft noise.(42)

To ensure that the findings of the EPA are given proper weight, section 611 of the Federal Aviation Act of 1958 (49 U.S.C. 1431) was modified to emphasize that agency's role. Under the revised section, the EPA is to propose regulations for the control of aircraft noise and sonic boom.(43) If the FAA fails to adopt its recommendations, EPA can request additional reviews(44) and require supplemental reports(45) when it feels the FAA's action does not adequately protect the public welfare. In addition, the new law makes specific provisions for citizen actions, stating that

> ...any person...may commence a civil action on his own behalf--
> (1) against any person...who is alleged to be in violation of any noise control requirement..., or
> (2) against--
> (A) the Administrator of the Environmental Protection Agency where there is alleged a failure of such Administrator to perform any act or duty under this Act..., or
> (B) the Administrator of the Federal Aviation Administration where there is alleged a failure of such Administrator to perform any act or duty under section 611 of the Federal Aviation Act of 1958....(46)

All of these provisions are designed to tighten standards set for aircraft noise emissions through direct and indirect government and public pressures.

Federal Preemption -- Both Public Laws 90-411 and 92-574 make it clear that Congress did not intend to preempt local control over noise impact. Although the immediate community may be in the best position to assess its own noise problems, it is not clear if this type of control could be implemented locally without severely restricting interstate commerce through myriad local rules and regulations that could have national impact.

Although the courts have allowed various local regulations that do affect interstate commerce,[47] none have touched on control of aircraft or the air system but rather have concentrated on trucks, trains or barges that are relatively slow and remain in a state for some length of time. In fact, much of their activity may be constrained to a relatively local geographic area. If a city regulates truck noise, most of the trucks affected are used primarily in the city. Interstate truckers can either comply, reroute their trucks around the area or use remote terminals, without significantly affecting their over-all operations. In contrast, a modern jet airplane theoretically could either touch or pass over practically every state in the country in a 24-hour period. There is no chance to stop at state borders to transfer crew members or change to quieter aircraft. If each city on an air carrier's routes set different standards, the carrier would be forced to either abandon service to points with restrictions that it could not meet, buy planes that would meet the strictest standards even though they would not be necessary at other points or buy different models of aircraft to serve particular cities based on their noise limits. None of these alternatives is practical or desirable.

The Court has considered the legislative history of Public Law 90-411 and concluded that, in spite of the Congressional intent,

> ...air commerce by reason of its speed and volume, requires a single authority in control if it is to be conducted at maximum safety and efficient use of the navigable airspace.
>
> The evidence discloses that air traffic is unique and should be controlled on the national level.(48)

In reaching this conclusion, the Court relied heavily on an earlier Supreme Court case where it was said

> Of course, air transportation, water transportation, rail transportation, and motor transportation all have a kinship in that all are forms of transportation and their common features of public carriage for hire may be amenable to kindred regulations. But these resemblances must not blind us to the fact that legally, as well as literally, air commerce, whether at home or abroad, soared into a different realm than any that had gone before....A way of travel which quickly escapes the bounds of local regulative competence called for a more penetrating, uniform and exclusive regulation by the nation than had been thought appropriate for the more easily controlled commerce of the past.(49)

On reviewing the decision, the Ninth Circuit Court of Appeals held

> The legislative history emphasizes the status of the one regulating the use of the airport, not the locus of the aircraft when the offensive sounds are produced. A State or local public agency, as the proprietor of an airport, can deny the use of its airport based on noise considerations; a State or local government cannot use its police power to do so.(50)

Since this case is presently under review by the Supreme Court, the issue of federal preemption versus Congressional delegation will be resolved shortly.

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VII. SOCIAL VALUE FUNCTION ANALYSIS

The first step in using the Social Value Function is to identify the various costs and benefits associated with the status quo. Then the relative changes in those costs and benefits can be computed for each policy alternative that could modify the present situation. The amount of each change can then be multiplied by the value of one unit of change to each individual affected. Finally, all values of all changes to all individuals can be summed to represent the value of a change in policy to a society as a whole. Mathematically, this is represented as

$$SV(x) = \sum_{i=1}^{N} \sum_{j=1}^{M} a_{ij} \, b_j \, (C/B_j)$$

where

$SV(x)$ = social value of policy x

C/B_j = cost or benefit j associated with the present activity

b_j = amount of change in cost or benefit j

a_{ij} = importance of one unit of change in cost or benefit j to individual i

M = total number of costs and benefits identified

N = total number of people affected by those costs or benefits.

Because of the impossibility of determining the personal value of each unit of change to each impact for each individual in a society, certain simplifying assumptions must be made. For example, individuals can be grouped and group values used for the value of changes in each cost or benefit. The number of people in the group times the group value equals the sum of the individual values for each person in the group. Often, the same group of people will be affected by each alternative. In this case, the change in the cost or benefit is directly proportional to the total change in value to the society, so it is not necessary to multiply each unit of change by each person's valuation for each policy alternative.

Applying these concepts to the airport noise problem, the present costs and benefits must first be determined. If the air system does not have to pay for noise costs, its service is less expensive and more people fly than if noise costs are part of air system costs. When more people fly, more money is spent in the local economy, more people are employed and the economic well-being of the area served by the airport is improved. Conversely, to the extent that noise abatement policies are imposed (and increase the cost of air service), the area economy will suffer. The economic loss represents the dollar-quantifiable disbenefits associated with noise reduction. Since the economic loss is eventually felt in some way by everyone in the region, all individuals are treated as one group which remains constant for each policy alternative. Therefore, economic loss is proportional to total social loss and must be minimized to maximize social value.

The non-dollar disbenefits of noise reduction are the inconveniences that result from fewer flights at higher costs. Some people may no longer be able to afford to fly. Others may not have flights available when they want them. These factors are extremely hard to quantify. They are, however, proportionate to the decrease in passengers, as are the dollar-disbenefits. Therefore, it can be assumed that changes in the dollar disbenefits will also represent changes in the non-dollar disbenefits and that both are minimized simultaneously. Since the relative merit of a given policy is equally reflected in both the dollar and non-dollar disbenefits, the non-dollar factors need not be specifically considered.

Second-order effects such as the loss of tax revenues from decreased employment and spending are impossible to quantify. Since the government will always raise the money it needs, the loss in tax revenues from one area will be made up by an increase in another. Tax losses are actually absorbed by the region as a whole, perhaps as a general tax rate increase. Although not quantifiable, this disbenefit also is logically assumed to be proportional to the total dollar disbenefit and, like non-dollar disbenefits, need not be specifically considered.

The major dollar-quantifiable benefits of noise reduction are the increases in local property values around the airport. Second-order effects on the tax base merely reallocate an additional part of the cost of government to those whose property has gone up in value. These people therefore do not realize all of their property appreciation but the society as a whole does. This increase in property values is concentrated around the airport and, as a result, the people affected are not the whole of the society. However, the same people around the airport are affected by each policy alternative and can be treated as a group.

The non-dollar benefits of noise reduction such as better sleep, peace of mind or easier communication are also concentrated in this same group. A recent study based on community surveys has correlated annoyance caused by aircraft noise to several psychological and social factors:

1. fear of aircraft crashing in the neighborhood;
2. susceptibility to noise;
3. belief in misfeasance on the part of those able to relieve the noise problem; and/or
4. belief in the importance of the airport and air transportation.

These factors can also be correlated to noise levels.[1] Therefore, changes in noise levels will be used as a proxy to represent changes in these non-dollar values.

With these simplifications in mind, the Social Value Function used to evaluate the impact of various airport noise control proposals becomes

$$SV(x) = \sum_{i=1}^{N} \sum_{j=1}^{3} a_{ij}\, b_j\, (C/B_j)$$

where C/B_1 = change in noise levels (and, as such, a proxy for all non-dollar-quantifiable benefits of noise reduction)

C/B_2 = increase in property values (the dollar benefit of noise reduction)

C/B_3 = economic loss to the region (the dollar disbenefit of noise reduction and also a proxy for other non-dollar-quantifiable disbenefits)

$b_{1,2,3}$ = amount of change in C/B_1, C/B_2 and C/B_3 for each policy alternative

$N = N_E + N_{NE}$ = total number of people in the region

where N_E = number of people exposed to noise

N_{NE} = number of people not exposed to noise

$a_{N_E 1}$ = value of a unit of change in noise levels to people exposed to noise

$a_{(N-N_E)1}$ = value of a unit of change in noise levels to people not exposed to noise (assumed = 0)

$a_{N_E 2}$ = value of a unit of property value increase to people exposed to noise

$a_{(N-N_E)2}$ = value of a unit of property value increase to people not exposed to noise (assumed = 0)

a_{N3} = value of each unit of economic loss to each individual in the region

For example, for two policies X and Y, if $b_{1,2,3}$ for X is 1,2,3 and for Y is 4,5,6, the Social Value Functions could be written

$$SV(X) = a_{N_E 1} \times 1 + a_{N_E 2} \times 2 + a_{N3} \times 3 \text{ , and}$$

$$SV(Y) = a_{N_E 1} \times 4 + a_{N_E 2} \times 5 + a_{N3} \times 6 \text{ .}$$

Subtracting the two Social Value Functions to evaluate the relative merit of the two policies yields

$$SV(Y) - SV(X) = (4\, a_{N_E 1} - 1\, a_{N_E 1}) + (5\, a_{N_E 2} - 2\, a_{N_E 2}) + (6\, a_{N3} - 3\, a_{N3})$$

$$= a_{N_E 1}\,(4-1) + a_{N_E 2}\,(5-2) + a_{N3}\,(6-3) \text{ .}$$

Since the $a_{N_E 1}$, $a_{N_E 2}$ and a_{N3} remain the same for each policy alternative, they can be factored out of each equation.

Thus

$$SV(Y) - SV(X) = (4-1) + (5-2) + (6-3)$$

$$= (b_1(Y) - b_1(X)) + (b_2(Y) - b_2(X)) + (b_3(Y) - b_3(X)) .$$

Therefore, the change in social value is directly proportional to the change in b_j from one policy to another and the Social Value Function can be simplified to

$$SV(x) = \sum_{j=1}^{3} b_j \ (C/B_j) .$$

In this paper, costs of various proposals are computed on the basis of overall system cost increases. These costs are then applied to a given locality to compare policy impact on a region. The area served by Los Angeles International Airport has been selected because of the availability of regional data. Since the analysis is based on one region only, care must be taken in extending the findings to other areas. However, the relative merits of various proposals are logically the same in all places although the dollar amounts vary.

Several noise abatement approaches have been selected for study: three technological, one legislative and one judicial. These are compared with the base case of no policy change and the continued natural attrition of noise aircraft through planned retirement. The period of study from the present to 1985 has been chosen both because of the availability of data and because of increasing political pressure to take definite action soon. Needless to say, any of these alternatives could be adopted simultaneously or in various degrees or stages over that time period.

The technological solutions considered are a change in operational procedures, nacelle acoustical treatment and the introduction of an aircraft with new very quiet engines in 1980. Figure VII-1 shows the effect these procedures have on land area exposed to a given noise level as compared to the 1972 land area.

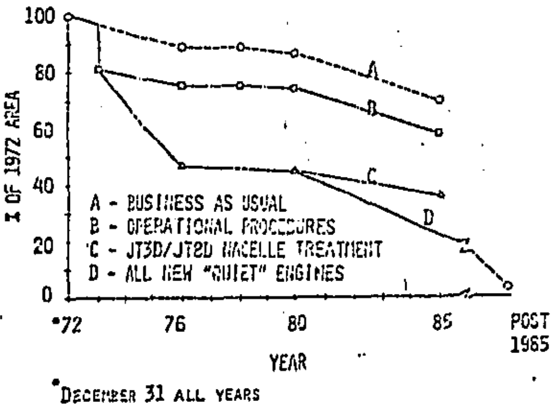

Fig. VII-1 Noise impact area as a function of abatement procedures & fleet modifications[2]

Two other approaches outlined in Section IV were considered but discarded: the design of a new fan assembly for present engines and the design of an entirely new engine for present aircraft. Although both approaches promise considerable noise reduction, their costs to the system have been estimated to be from 2 to 13 billion dollars respectively.[3] Because of the extensive engineering work yet to be done, it would probably be at least 1977 or after before either option could be ready for fleet installation.[4] At that time, many of the aircraft in the fleet would have only limited service life remaining. Therefore, it is better to bypass these options and concentrate on a completely new aircraft using an entirely new engine that could provide more sound reduction, offer better operating economics and start entering service by 1980. The few years' difference in time and the better results make the new aircraft/new engine option superior to either a refan or a new engine for present airframes.

The legislative solution considered is the imposition of a national 10 p.m. to 7 a.m. curfew at all carrier airports. More drastic measures such as forced land condemnation, mass relocation of airports or the introduction of alternate types of transportation were considered too expensive to be practical.

The judicial solution considered is a continuation of what seems to be a liberalizing trend toward more and larger recoveries for noise damages to the point where, at some date within the next five to ten years, all people within high-noise regions will be given compensation.

In considering these alternatives, all costs and benefits are estimated in constant present dollars. All values are compounded forward from the time of accrual to 1985 at 8% interest and the options compared at that date. It is assumed throughout that the population density around the airport will remain constant over the time period of the study.

Present Economic Benefits of Los Angeles International Airport to Its Region of Service

In 1970, the consulting firm of Waldo and Edwards, Inc. made an economic impact study of Los Angeles International Airport's contribution to the Los Angeles regional economy. Projections were also made for 1975 and 1980. The study was based on two surveys of airport employment and industry spending to determine contributions to the economies of Los Angeles, Orange, San Bernardino, Riverside and Ventura Counties.

Using survey results as a base, estimates were made of the payrolls and the direct and secondary employment generated by the air industry. Local purchases of services and materials and local taxes paid were also estimated as well as the expenditures of non-resident air passengers.(5) Table VII-1 summarizes the results.

Table VII-1

Economic Impact of
Los Angeles International Airport
on the Los Angeles Region
1970 - 1980

	1970	1975	1980
	(billions of dollars)		
Payroll (people employed by airport industry)	$1.440	$1.970	$2.425
Purchases of local goods and services	.258	.347	.430
Local taxes paid	.025	.034	.042
Expenditures by non-resident air passengers	1.587	2.120	2.627
Totals	$3.310	$4.471	$5.524

Growth of passenger traffic over this same time period has been estimated from 8 to 10½% annually.[6] Throughout this paper, it is assumed that economic impact is directly proportional to passengers carried; therefore, the impact of the airport on the region might also be expected to increase at the same annual percentage.

Los Angeles International Airport, however, is reaching its capacity limit in terms of the number of aircraft flight and ground operations that can safely be performed. Even using the most advanced traffic control techniques, only 50% more could be added to its capacity.[7] Although passenger capacity will increase at a somewhat greater rate because of the introduction of wide-bodied jets, additional airports will be needed to handle the total increase in demand.

With these factors in mind, the Los Angeles Department of Airports has estimated the growth at Los Angeles International Airport to be somewhat less than overall national projections.[8] It is assumed that the economic impact of the airport to the region will be proportionate to this growth rate. Table VII-2 summarizes this data. (Note the close correspondence to the Waldo and Edwards, Inc. study for 1975 and 1980.) Changes in this projected economic growth because of noise abatement policies will be used to measure the dollar cost of noise abatement to the region.

Table VII-2

Passenger Growth at Los Angeles International Airport and Its Corresponding Value to the Region

Year	Passengers Per Year (Millions)	Passenger Increase as % of 1970 Total	Value to Region Per Year (Billions of 1972 Dollars)
1970	21.2	0	$3.31
1971	20.5	-3.3	3.20
1972	22.0	2.3	3.39
1973	23.7	11.8	3.70
1974	26.7	25.9	4.17
1975	28.5	34.4	4.45
1976	30.5	43.9	4.76
1977	32.0	50.9	4.99
1978	33.0	55.7	5.15
1979	34.0	60.4	5.31
1980	35.0	65.1	5.46
1981	36.0	69.8	5.62
1982	36.7	73.1	5.73
1983	37.2	75.5	5.81
1984	37.5	76.9	5.86
1985	38.0	79.2	5.93

<u>Cost of Noise Reduction to the Region</u>

Cost impact on a region is determined in the following manner:

1. The percentage increase in system operating costs is estimated for each proposal.
2. It is assumed that this increase will be passed on to the user as a fare or rate increase.
3. This will in turn reduce the volume of passengers and freight traffic. An elasticity of -0.7 is used (the most recent Civil Aeronautics Board estimate for passenger service).[9] The same elasticity is assumed for freight.
4. It is assumed that the average system-wide traffic reduction will be experienced in the region to be studied (Los Angeles) and that employment and expenditures associated with air service will be reduced in the same percentage as traffic reductions.
5. Finally, it is assumed that some portion of those unemployed will find other jobs in the area, that some of the money that would have been used to buy air service will be spent for alternative services and that the economic impact to the region will thus be lessened.

To estimate the range of absorption of potential loss by the region, several assumptions are made:

a. Most of those who lose their jobs at the airport are clerical, ticket or rental car agents, maintenance personnel, etc., with an average salary of $200/week or less and would be entitled to unemployment compensation of $75/week. Therefore, even if all remained unemployed, 37.5% of their former income would still be circulating in the area.

b. At the other extreme, it can be assumed that the labor pool is large enough to absorb the unemployed to the same extent as the general unemployment level. Assuming a 5% unemployment rate, 95% of the wage base would remain in the community.

c. In reality, some people will find better jobs, most will find lower-paying jobs, some will go onto unemployment rolls and eventually welfare and some will leave the region. Therefore, it is assumed that 75% of the wages will be regenerated in other ways and the economic loss to the region is 25%.

d. It is assumed that spending by travelers from out of the region will be decreased by the same percentage as the traffic decreases. However, there are people in the region who will not travel outside it because of the fare increase. Money they would have spent for travel is therefore available for spending in the region. It is assumed that this would offset half the lost spending by travelers from out of the region.

e. Since the wages and expenditures of the air system and the expenditures of travelers are each about 50% of the total economic impact to the region (see Table VII-1), the above assumptions yield the following measure of impact on the region. For a decrease in traffic, there will be a 50% decrease in area economics because of reduced tourist spending. However, half of this will be made up by additional in-area spending by residents who would have traveled if there were no fare increase. Likewise, there would be a 50% decrease in area economics because of unemployment. However, 75% of this will be recovered by people taking other lower-paying jobs. As a result, the total economic loss to the region due to a traffic decrease would be $(50\% \times \frac{1}{2}) + (50\% \times \frac{1}{4}) = 37.5\%$.

f. If this is combined with the demand elasticity, a 1% cost increase would yield a .7% traffic decrease. Multiplied by .375, this would lead to a .26% loss in area economics.

The Cost of Doing Nothing

If no additional costs are imposed by noise control measures, the benefits of air service to the Los Angeles region can be expected to grow as shown in Table VII-2. To provide enough capacity to meet this forecast growth, the air system will be investing heavily in new aircraft over the next few years. It is assumed that this cost can be absorbed without a fare increase due to the corresponding increase in traffic. Noise reduction costs, however, will be over and above the planned expenditures and will ultimately be passed on to the passenger as a fare increase.

The basic capital costs of the industry have been estimated by the Air Transport Association to be $7 billion from 1971 to 1975 and $15 billion from 1975 to 1980.[10] Assuming the investment rate for 1980 to 1985 will be the same as the 1975 to 1980 period and that the investment over any period is evenly distributed, these figures represent an investment rate of $1.4 billion per year from 1971 to 1975 and $3 billion per year from 1975 to 1985. Depreciating these new aircraft over a 15-year period to zero residual value (Present Civil Aeronautics Board guidelines for rate-making purposes are 14-16 years to 10%.[11]), each $1.4 billion invested during the period 1971 to 1975 will add $93 million to annual depreciation charges in each of the 15 years after its investment and each $3 billion invested from 1975 to 1985 will add $200 million annually over a similar time period. Table VII-3 shows the cumulative effect of this depreciation from 1971 to 1985.

Table VII-3

Cumulative Annual Depreciation Costs
for Planned New Aircraft Acquisition -- 1971-1985
(Millions of 1972 Dollars)

Year	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986 and beyond
15 year depreciation of $1.4 bill. annual investment	$93	93 93	93 93 93	93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	93 93 93 93 93	0 93 186 279 372
15 year depreciation of $3 bill. annual investment						200	200 200	200 200 200	200 200 200 200	200 200 200 200 200	200 200 200 200 200 200	200 200 200 200 200 200 200	200 200 200 200 200 200 200 200	200 200 200 200 200 200 200 200 200	200 200 200 200 200 200 200 200 200 200	1000 1200 1400 1600 1800 2000 2200 2400 2600 2800
Increase in annual depreciation over 1970 base	$93	186	279	372	465	665	865	1065	1265	1465	1665	1865	2065	2265	2465	

The Cost of a $6^{o}/3^{o}$ Landing Procedure

This option can be flown under visual conditions without any additional electronics. In bad weather, however, new transmission devices at the airport and new receivers on board the aircraft are needed. Since the entire air traffic and landing control systems of this country are presently under revision and since the new landing aids will probably be microwave instrument landing systems compatible with this type of approach, much of the cost can be absorbed in the natural growth of the air traffic control system. The incremental cost of using this appreach technique with present aircraft in the present system is all that need be estimated.

Assuming that there are only 25 major hub airports with severe enough noise problems to justify early installation of microwave systems and that each airport would instrument four runways: The cost per runway would be \$40,000 and the cost per aircraft would be \$4,000.[12] It is anticipated that there will be 2,236 aircraft in the commercial fleet in 1973.[13] Therefore, the total airport cost would be \$4,000,000 and the total aircraft cost would be \$8,944,000. Assuming a five-year depreciation, the increase in annual depreciation costs would be \$2,590,000 per year. Based on the data in Table VII-3, this would increase depreciation costs .92% in 1973, .69% in 1974, .55% in 1975, .38% in 1976 and .29% in 1977. Depreciation costs represent approximately 10% of the total operating costs of the system.[14] The total cost increase and associated fare increase would be 1/10th the above numbers. Table VII-4 summarizes the results of these costs and their impact on the Los Angeles region.

Table VII-4

Economic Impact on the Los Angeles Region
from the Implementation of a $6^{o}/3^{o}$ Glide Slope

Year	Annual System Cost Increase (%)	Resulting Business Loss (%) (a)	Base Line Economic Value to Area (Billions of 1972 Dollars) (b)	Resulting Business Loss Per Year (Millions of 1972 Dollars) (c)	Resulting Business Loss Per Year at 8% Interest to 1985 (Millions of 1972 Dollars) (d)
1973	.092	.02	3.70	.74	1.86
1974	.069	.02	4.17	.83	1.93
1975	.055	.01	4.45	.45	.97
1976	.038	.01	4.76	.48	.96
1977	.029	.01	4.99	.50	.92
				Total	6.64

(a) elasticity (.7) x % business loss (37.5) x % annual system cost increase

(b) From Table VII-1

(c) % business loss x base line economic value

(d) business loss per year x compound interest factor at 8%[15]

The Cost of Quiet Nacelles

The total cost of nacelle treatment has been estimated at $475 million for the 707/DC8, 727 and DC9/737 fleets that would still be in use in 1980,[16] while the depreciation period for such modifications has been estimated at 5 to 10 years.[17] Using the longer term to minimize cost increase and basing the implementation over the three-year period from 1974 through 1976, the average annual investment would be $158.3 million, resulting in a $15.83 million depreciation charge for the first year, $31.66 million for the second year and $47.49 million for the third and subsequent years until 1984 when the first year's investment would be fully depreciated. Using the same method for estimating the economic impact on the area as was used for the $6^{\circ}/3^{\circ}$ approach, the loss to the area would be $102,620,000 over the 1973 to 1985 period.

The Cost of New Quiet Engines and Aircraft

The introduction of a totally new aircraft using a totally new quiet engine in 1980 would have very little impact on the air system so long as the cost per seat were the same as or less than that for wide-bodied aircraft available at the same time. If the cost per seat were comparable, then the industry could purchase such aircraft in place of some of the wide-bodied equipment it would otherwise buy.

The new aircraft would be smaller than the wide-bodied jets since it would not be designed as a competitor to these aircraft. Rather, it would be a replacement aircraft for the smaller 727, 737 and DC-9. The current cost per seat of these aircraft is approximately $40,000 compared to $50,000 for the wide-bodied jets (based on maximum seating densities[18]). Part of this difference is attributable to inflation in development costs since the smaller aircraft were designed about five years earlier; part of the difference is a result of the longer-range requirements of the larger aircraft; and part of the difference is in the size of the production run.[19] Of these factors, the size of the production run is the most important. If enough aircraft are produced, the total cost per aircraft approaches the actual production cost as development costs are written off against more aircraft.

Because of the large number of 727s, 737s and DC-9s that could be replaced, the production run for the new aircraft would be quite large (even assuming that two manufacturers would enter the market). In addition, there is growing pressure for a smaller version of the same aircraft to replace the turbo-prop equipment of the local service airlines,[20] which would increase the production run to an extent also.

For all these reasons, it seems quite possible that a 125 to 175 passenger airplane could be designed using new quiet high-bypass fanjet engines at a seat cost that approximates the $50,000 of wide-bodied aircraft. Therefore, the introduction of such an aircraft would not impose any additional costs on the air system beyond what is already anticipated.

The Cost of a National 10 p.m. to 7 a.m. Curfew

Although the cost of a curfew at one airport may not seem significant, the true cost impact is felt when the curfew is national. In fact, the total system cost increase has been estimated as high as 25%.[21] Because there is little factual data available on the costs of curfews, the implications of this policy alternative require more detailed analysis than the preceding alternatives.

The impact of a curfew can be broken down into four areas:

1. impact on passenger service
2. impact on air cargo service
3. impact on mail and express
4. impact on maintenance and repair activities

In evaluating curfew costs, the worst case (a nationwide 10 p.m. to 7 a.m. curfew) has been assumed. Actually, there are some airports where no curfew would be needed or where less restrictive limits could be imposed. The transfer of some maintenance and freight operations to these airports would lessen the economic loss to an area.

Impact on Passenger Service -- Using the Official Airline Guide,[22] a survey was made of the arrival patterns of passenger aircraft at several airports across the country, including Los Angeles International. Only about 15% of passenger aircraft movements occur between 10 p.m. and 7 a.m. and, of that number, about half are within an hour of the curfew limits. Therefore, at least one-third of curfew-affected flights could be rescheduled to arrive or depart during non-curfew hours. The remainder could not effectively be rescheduled and would represent an overall decrease in airline capacity of about 10% (2/3 of 15%). Approximately half of this capacity might not be replaced directly but could be absorbed on non-curfew flights by increasing their load factor. To replace the remaining 5%, however, the airlines would have to buy new equipment to compensate for decreased aircraft utility and scheduling flexibility. The corresponding increase in fleet size would raise annual depreciation costs over presently planned expenditures by 5%. Since depreciation represents about 10% of the total operating costs, the change in overall cost because of the additional aircraft would be 0.5%.

Additional flight crews would be needed to operate these new aircraft. Since crew costs represent about 13% of the total operating costs,[23] a 5% increase in crews (corresponding to the 5% increase in the number of aircraft) would raise the overall operating costs 0.65% (13% of 5%). Based on these figures, the total increase in operating costs caused by a 10 p.m. to 7 a.m. curfew would then be the sum of the 0.5% depreciation increase and the 0.65% crew costs increase or 1.15% annually.

Using the same assumptions and procedures derived for the analysis of prior alternative policies, this 1.15% increase in costs creates a .30% decrease in area economic benefit (1.15% x .26). Assuming the curfew were imposed in 1973, the total loss compounded forward at 8% to 1985 would be $320,000,000 resulting from the impact on passenger service.

Impact on Air Cargo Service -- Since approximately 50% of air cargo moves in passenger aircraft, the impact of a curfew on this portion of the business would be included in the passenger service calculations. The remaining 50% moves in all-cargo aircraft which fly almost exclusively at night.(24)

It is difficult to estimate the impact on system economics if a curfew required a rescheduling of these aircraft since the carriers themselves (other than exclusive air cargo carriers) have little feel for the value of cargo business. As recently stated by Eastern Airlines' Division Vice-President for Cargo Sales and Services,

> In discussing the economics of Air Cargo from the carrier point of view, the first premise is that the combination carriers...really do not know precisely the costs associated with providing a viable cargo service; thus the debate rages as to the profitability of cargo--the result, an unwillingness to make commitments to the cargo business as freely as they are made to passenger development.(25)

It is clear that all-cargo operations lose money in general. The extent of this loss was reported in a presentation by a member of the Civil Aeronautics Board staff who said

> ...For a number of years, domestic all-cargo services have generally been conducted at operating losses. For only two 12-month periods since 1963... have the operating revenues from such services, including a minor proportion of mail and express, exceeded operating expenses. For the 12 months ended December 31, 1971, domestic trunk and all-cargo carriers reported operating revenues of $259 million and operating expenses of over $294 million resulting in an operating loss of $35 million for [all-cargo operations].(26)

Nighttime operations are at least part of the reason for this loss. Because of the traditional service pattern of overnight delivery, there is a large influx of shipments into the freight terminals after the close of business of shipper firms. The resulting congestion often exceeds the ability of the freight facility to handle the shipments. Additional people must be employed (at evening rates) for these peaks and must be paid a full day's wage even if they are needed only for a few hours. (This reduces the productivity of employees in the air cargo industry to about 1/10th of that in the trucking industry.[27]) After the peak, the facilities stand nearly idle until the next evening. As a result of this cyclic peaking then idle capacity, at least one-half of the costs of moving air freight are for ground handling.[28]

Thus the carriers themselves would prefer to transfer a large part of their cargo activities to day hours to spread the traffic flow and make better use of manpower and facilities. With the advent of the wide-bodied jets with their large cargo compartments, the airlines are now able to move more freight during the day on scheduled passenger flights. In fact, the use of such "belly" capacity can greatly improve the profitability of passenger flight and offset the low load factors often experienced on wide-bodied aircraft.[29]

For all these reasons, the elimination of all-cargo flights at night might actually improve the financial performance of the air system rather than create additional costs. However, the airlines contend that all-cargo service cannot be evaluated apart from overall system cargo service because the existence of freighters, properly marketed, generates traffic for the total fleet. Often more traffic will be delivered for a freighter flight than can be accomodated so the overflow moves as belly freight on passenger flights. Also, once a shipper has stopped to make one delivery, he may use the same airline to ship additional goods to other places rather than go to other terminals.[30] Airlines also argue that nighttime capacity will be required in the future because of the rapid expansion of the air cargo business (as indicated by the 400% increase in the overall volume of domestic airfreight from 1960 to 1970 and the even greater growth rate for all-cargo aircraft traffic.[31])

It is impossible to evaluate the importance of these factors or to predict how they might change if all-freight aircraft were still available but required to fly by day. Rather than attempt to quantify the effects of a curfew on shipments by examining the carrier's performance, it may be useful to examine the needs of the shipper.

Air cargo shipments can be placed in three distinct categories:

1. routine planned traffic that could be diverted to surface transportation because it is not perishable;
2. routine perishable traffic that is time-sensitive, but its movement is planned in advance; and

3. emergency traffic which is unplanned and highly time-sensitive.(32)

A curfew would have little effect on the first two, since day freighter service could be planned as an alternative. Also, since these types of shipments can be anticipated and containerized more easily than unplanned emergency traffic, they represent lower cost to the airlines. Thus a marketing thrust can be anticipated in the direction of high-density, high-volume regular movements with a corresponding de-emphasis on emergency cargo.(33)

The real impact of a curfew on air cargo movements is on the emergency shipments. It is estimated that 25 to 75% of all air freight is emergency traffic or at least perceived to require emergency shipment by the shipper.(34) It can be assumed that most of these shipments are not perishable, since a shipper of perishable goods would normally anticipate and plan his shipments in advance. Therefore, a few hours delay in most "emergency" traffic will result primarily in inconvenience, not spoilage.

The emergency market can be divided into two geographic markets--one where alternate service by truck exists and one where it does not. If truck service is a viable alternative, then most emergency shipments probably already move by truck because the cost is about half that of air service.(35) Assuming an average speed of 50 miles per hour for trucking, a pickup made at 5 p.m. could be delivered anywhere within a 750-mile radius by

8 a.m. the next morning. Assuming a 500-mile-per-hour speed for aircraft, a jet could also provide overnight service in this market if it could depart before 8:30 p.m. (in order to arrive before the 10 p.m. curfew is enforced). If the plane could not depart until 7 a.m. the next morning, it still would provide faster service than the truck for distances beyond 850 miles (the distance of an overnight truck drive plus the additional distance the truck could travel in the two hours necessary for the plane to overtake it). Over greater distances, aircraft would have a clear speed advantage. Therefore, much of the emergency traffic that moves by air today would still go by air since there is little alternative. The difference would be that shipments would not arrive as quickly as they do today.

The major problem would be for emergency shipments moving east since time zone changes decrease the apparent speed of aircraft. To arrive on the east coast before 10 p.m., a flight would have to leave the west coast before 2 p.m. (5 hour flight plus 3 hour time zone change). This would essentially preclude any shipments that could not be picked up from the shipper before 10 or 11 a.m. Alternatively, it would be possible for a plane to depart the west coast at 10 p.m., delay one hour in flight and arrive on the east coast at 7 a.m. (5 hour flight plus one hour in-flight delay plus 3 hour time zone change). This would increase the cost of such a flight by 20% because of the hour delay, but the cost could be passed along to the shipper if he really desired next-day delivery.

Failing either of these two options, the shipper would have to wait for a 7 a.m. departure the next morning, arriving on the east coast at 3 p.m. with little likelihood of delivery until the following morning. With these alternatives in mind, the shipper would probably become more conscious of which shipments were really emergency and which were not, paying the premium for overnight service only when it was justified.

Summarizing these effects:

1. The 50% of air cargo that presently moves in passenger aircraft would not be affected by a 10 p.m. to 7 a.m. curfew.
2. Between 25% and 75% of the remaining traffic is "emergency" traffic. Assuming the actual number is 50%, then 50% of the freighter traffic presently moving at night is non-emergency and could be diverted to day flight.
3. The 50% emergency traffic moving at night is 25% of the total air cargo traffic. In most cases, next day delivery could still be achieved by either getting the goods to the airport in time for a pre-curfew departure or by settling for a mid-day delivery the next day, based on a post-curfew departure. Since the shipper has little alternative, he would still use air service for most of these shipments although it would not be as convenient as without the curfew.
4. The greatest impact on traffic is on shipments moving from the west coast to the east coast. Assuming that half

the total air cargo moves north-south and half moves east-west, then only half of the 25% (or 12.5%) of the total traffic that represents emergency shipments moves in the cross-country direction. The half of this that moves east to west is much less sensitive to curfew effects.[36] Of the remaining traffic moving west to east, perhaps only half is transcontinental. The rest is distributed at lesser distances and therefore capable of mid-day delivery on the next day after shipment. Therefore, only 3.125% of the total air cargo traffic (transcontinental eastbound emergency traffic presently moving in night freighters) could be severely restricted by a curfew.

5. However, this 3.125% of the traffic could still move on an overnight freighter by paying a 20% premium. Assuming the .7 elasticity used for passenger traffic (which is not unreasonable since "emergency" traffic is relatively insensitive to price changes), 14% (17 x 20% rate premium) of 3.125% would be lost. Thus the total air cargo traffic loss attributable to a curfew would be 0.4375%.

6. Since domestic air cargo shipments provide about 6.5% of total air system revenues,[37] this traffic loss would decrease revenues by .028% (6.5% x .004375). Based on total system revenues of $9.6 billion,[38] the loss would be about $2.68 million.

Even if the assumptions made in this analysis are much too low and in reality 75% of the traffic is emergency, 75% of all traffic is in the cross-country markets of which 75% moves west to east and 75% of this amount is transcontinental, the resulting revenue loss would be only about $15 million. To put this into perspective, it has recently been estimated that the security procedures just adopted by the airlines are costing $150 million or more.[39] The Civil Aeronautics Board has allowed a 34 cent fare increase per ticket to cover these costs,[40] approximately a .7% average fare increase. Since the $15 million loss of air cargo revenue under the maximum loss assumption would be only 1/10th the security cost, the average passenger fare increase would be 3.4 cents or .07%. Using the same elasticity and area loss factors as before, this would be approximately $30 million--a .02% loss in economic benefit to the Los Angeles area or less than 1/10th the size of the impact of additional aircraft purchases.

Impact on Mail and Express -- Mail traffic represents about 3.3%[41] and express about .4%[42] of total system revenues, approximately half that of cargo. Following a similar type of analysis, the impact of a curfew on air system costs and revenues due to changes in the carriage of mail are very small. Here, however, public convenience may be more important.

Most of the country could still receive one-day delivery from other areas if the postal service were to shift its delivery service to afternoon, allowing most north, south and westbound flights to leave at 7 a.m. and arrive in time to distribute the mail. In lieu of this, a change in postal pickups could allow earlier sorting and delivery to planes in time to depart early evening and still arrive in time for night sorting and next-morning distribution of mail. In short, a great deal of the inconvenience could be minimized by revised pickup and delivery services.

The worst case, as with cargo, is overnight service from the west coast to the east coast. But again, premium service could be available on departures just prior to the start of the curfew.

Banks would perhaps be hurt most by delayed express deliveries. It has been estimated that a curfew would cost New York banks $34.8 million per year in lost interest because of delays in handling transactions between banks, the Federal Reserve and the bank clearing houses.(43) It can be assumed, however, that much of this loss could be regained by earlier processing by using computers or hiring additional personnel, so that shipments could be made on earlier flights. The cost of these measures would be considerably less than the potential loss of interest and actually benefit the regions involved by higher employment.

Impact on Maintenance and Repair Activities -- In the Lockheed case,(44) the district court opinion spent some time discussing the potential impact of a curfew on maintenance and repair activities, concluding that considerable cost increases would result. However, it is doubtful whether this would really occur. About 2% of all present flights are non-revenue operations connected with maintenance, training or movements to reposition equipment.[45] Most of these are planned well in advance, however, so those influenced by a curfew could be eliminated by schedule changes. In addition, because of the high reliability of present jet aircraft, most maintenance is done on an as-needed basis. Many airports are already equipped to do various minor repairs and back-up aircraft are available if major repairs require an empty flight to a repair base. Thus the unnecessary duplicate facilities feared by the court either already exist or are really not needed. In either case, the additional aircraft purchases required as a result of rescheduling passenger service would provide enough flexibility to alleviate many of the scheduling and planning problems associated with maintenance activities.

Summary of Curfew Costs -- Although a curfew would affect maintenance, mail and express, air cargo and passenger operations, the major impact on the system would be through the purchase of additional aircraft to make up the capacity lost by the inability to move aircraft at night. The effects of cargo are about 1/10th this amount and other effects are insignificant by comparison. In the Los Angeles area, the combined impact of additional aircraft purchases and cargo losses would result in $350 million in lost wages, purchases of supplies and visitor spending during the period from 1973 to 1985.

The Benefits of Noise Reduction

In the Los Angeles area, it is estimated that between 40,000 and 60,000 families live in areas exposed to a Noise Exposure Forecast (NEF) of 30 or more,[46] a relatively high noise level. (See Appendix A for a definition of NEF and other noise measurement techniques used in this section.) Using the higher estimate and an average of 2.7 people per family,[47] this totals 162,000 people. Assuming a uniform distribution of these people within the 30 NEF contour, a given percent reduction in contour area represents the same percent reduction in overall community annoyance.[48] Therefore, multiplying the annual percent reduction in land area exposed to 30 NEF by 162,000 people yields the reduction in the people's annoyance for the year. If this is then multiplied by the number of years between the time of the reduction and 1985, the result is the reduction in people-years-of-annoyance,[49] the measure of non-dollar benefits used in this analysis.

To determine the dollar benefits resulting from noise reduction, the value for a unit of NEF reduction is multiplied by the amount of reduction and by the number of dwellings affected (assuming one dwelling unit per family). The value of a unit of noise reduction per dwelling unit has been estimated between \$110[50] and \$360[51] per decibel. For this analysis, an average value of \$200 per unit of NEF is used. Since 60,000 family units are within the contour at present, each unit of NEF reduction in the Los Angeles area would be worth \$12,000,000 to the community.

Using the relationships between exposed land area changes and the change in decibels of noise level developed in Appendix B, the yearly percent area reductions as determined from Figure VII-1 can be converted to a corresponding change in NEF. (In the case of a curfew, the change in NEF computed in Appendix C is converted to land area change by the reverse process.) The corresponding total change in land value can then be computed and the result compounded at 8% interest to 1985. Table VII-5 is a sample of these calculations.

Table VII-5

Calculation of Non-Dollar and Dollar Benefits of Policy Alternative A (Business as Usual)

Year	% 1972 Area (a)	Yearly Change in %	Yearly Reduction in People Annoyance (b)	People-Years-of-Annoyance to 1985 (c)	Total Change in NEF (d)	Yearly Change in NEF	Yearly Change in Property Value (Millions) (e)	8% Interest Factor	Yearly Change in Property Value with 8% Interest to 1985
1972	100.0	---	---	---	---	---	---	---	---
1973	97.5	2.5	4,050	52,650	.110	.110	$1.32	2.52	$3.33
1974	95.0	2.5	4,050	48,600	.223	.113	1.36	2.33	3.17
1975	92.5	2.5	4,050	44,550	.339	.116	1.39	2.16	3.00
1976	90.0	2.5	4,050	40,500	.485	.146	1.75	2.00	3.50
1977	90.0	0.0	0	0	.485	.000	0.00	1.85	0.00
1978	90.0	0.0	0	0	.485	.000	0.00	1.71	0.00
1979	88.0	2.0	3,240	22,680	.555	.070	0.84	1.59	1.34
1980	86.0	2.0	3,240	19,440	.655	.100	1.20	1.47	1.76
1981	82.8	3.2	5,184	25,920	.820	.165	1.98	1.36	2.69
1982	79.6	3.2	5,184	20,736	.991	.171	2.05	1.26	2.58
1983	76.4	3.2	5,184	15,552	1.169	.178	2.14	1.17	2.50
1984	73.2	3.2	5,184	10,368	1.355	.186	2.23	1.08	2.41
1985	70.0	3.2	5,184	5,184	1.549	.194	2.33	1.00	2.33

Total: 306,180 People-Years-of-Annoyance

Total: $28.61 Million Appreciation in Land Value

(a) From Figure VII-1
(b) Yearly % change x 162,000 people
(c) Yearly reduction in people annoyance x number of years to 1985
(d) As computed by methods in Appendix B
(e) Yearly NEF change x $12,000,000 1972 dollars

Benefits of a Curfew

Most techniques for measuring the cumulative effects of aircraft operations over time place a heavier annoyance weighting on nighttime operations than those during the day. The Noise Exposure Forecast method used in this paper considers a flight between 10 p.m. and 7 a.m. to be almost as offensive as 17 flights at any other times. As a result, the elimination of these heavily weighted night operations through the imposition of a curfew yields a dramatic reduction in NEF levels with a corresponding decrease in the land area within any given NEF contour. Applying the mathematical techniques developed in Appendices B and C and the assumptions used in determining curfew costs (that 15% of the present total operations occur during the proposed curfew period, 1/3 of the cancelled flights could be shifted to non-curfew hours and 1/3 could be rescheduled with new aircraft), calculations show that a 10 p.m. to 7 a.m. curfew would reduce the land area exposed to any NEF level by 74%. This reduction would be in addition to any other noise abatement technique employed and would be based on the total land area exposed at the time of the curfew's implementation.

For example, in the Business as Usual case the land area exposed to 30 NEF would be 70% of its present size in 1985. A curfew imposed at that time would reduce this by 74% so that the resulting exposed land area would be only 18.2% of the 1972 area. If, instead of Business as Usual, the $6^{o}/3^{o}$ glide slope, quiet nacelles and the totally new aircraft options were implemented, the 1985 land area would be reduced to 20% of its present size. A curfew imposed in 1985 would then reduce this amount by 74% leaving 5.2% of the present land area exposed to 30 NEF.

Combining curfew calculations with the techniques for computing dollar and non-dollar benefits (as used in Table VII-5), the benefits arising from each policy alternative can be computed and added to those benefits which accrue concurrently from the Business as Usual case (Table VII-6).

Table VII-6

Comparison of Total Non-Dollar and Dollar Benefits of Noise Abatement Policy Alternatives with the Addition of a 10 p.m. to 7 a.m. Curfew Imposed in 1973

Policy Alternative	Non-Dollar Benefit (Decrease in People-Years-of-Annoyance as of 1985)		Dollar Benefit (Increase in Property Value as of 1985 in Millions of 1972 Dollars)	
	without curfew	with curfew	without curfew	with curfew
Business as Usual (A)	306,180	1,660,000	28.6	206.2
A + $6^{\circ}/3^{\circ}$ Glide Slope (B)	583,200	1,716,000	52.3	227.9
A + Nacelle Treatment (C)	805,950	1,791,000	82.9	265.8
A + New Quiet Aircraft (D)	383,940	1,686,000	63.5	239.4
A + B + C	1,082,970	1,847,000	106.6	287.5
A + B + D	660,970	1,742,000	87.2	261.1
A + C + D	883,710	1,817,000	117.8	299.0
A + B + C + D	1,160,730	1,873,000	141.5	320.7

Computation of the Social Value Function

The social value of each proposed noise abatement alternative can now be calculated by combining the change in benefits to the area with the change in costs for each alternative. The social value of policy alternatives A (Business as Usual) and A + B (Business as Usual plus Operational Procedures) are calculated in detail below. The results for all options are summarized in Table VII-7.

SV(A) = 306,180 reduction in people-years-of-annoyance

+ $28.6 million increase in property values

- $0 cost to region beyond presently-planned expenditures

= 306,180 + $28.6 million

SV(A + B) = 583,200 reduction in people-years-of-annoyance

+ $52.3 million increase in property values

- $6.6 million cost to region beyond presently-planned expenditures

= 583,200 + $45.7 million

Table VII-7

Social Value Functions
for Noise Abatement Policy Alternatives

Policy Alternative	Non-Dollar Benefit (Decrease in People-Years-of-Annoyance)	Dollar Costs and Benefits (in Millions of 1972 Dollars)		
		Benefits	Costs	Net Cost
1. SV(A)	306,180	$ 28.6	$ 0.0	$-28.6
2. SV(A+B)	583,200	52.3	6.6	-45.7
3. SV(A+C)	805,950	82.9	102.6	19.7
4. SV(A+D)	383,940	63.5	0.0	-63.5
5. SV(A+B+C)	1,082,970	106.6	109.2	2.6
6. SV(A+B+D)	660,970	87.2	6.6	-80.6
7. SV(A+C+D)	883,710	117.8	102.6	-15.2
8. SV(A+B+C+D)	1,160,730	141.5	109.2	-32.3
9. SV(A+E)	1,660,000	206.2	350.0	143.8
10. SV(A+B+E)	1,716,000	227.9	356.6	128.7
11. SV(A+C+E)	1,791,000	265.8	452.6	186.8
12. SV(A+D+E)	1,686,000	239.4	350.0	110.6
13. SV(A+B+C+E)	1,847,000	287.5	459.2	171.7
14. SV(A+B+D+E)	1,742,000	261.1	356.6	95.5
15. SV(A+C+D+E)	1,817,000	299.0	452.6	153.6
16. SV(A+B+C+D+E)	1,873,000	320.7	459.2	138.5

A = Business as Usual
B = Operational Procedures
C = Nacelle Treatment
D = All New "Quiet" Engine
E = National 10 p.m.-7 a.m. Curfew

The goal of any policy alternative should be to maximize benefits while minimizing cost. When a given policy provides more benefit at lower cost than an alternative policy, it is therefore preferable. To analyze the Social Value Function results shown in Table VII-7 in this respect, it is helpful to relate the net cost to society and the amount of reduction in people-years-of-annoyance for each option (Figure VII-2).

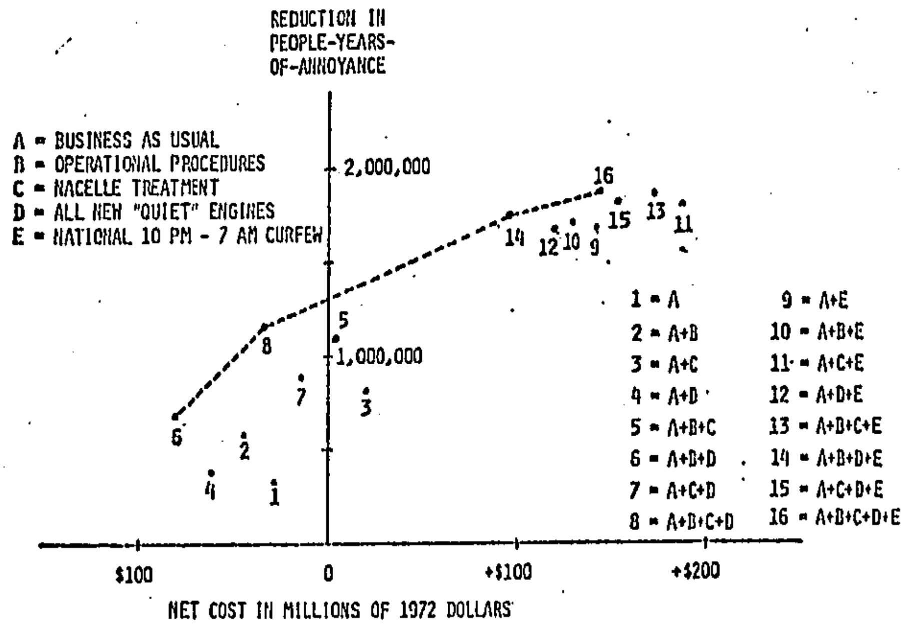

Fig. VII-2 Social Value Functions for Noise Abatement Policy Alternatives (The broken line connects those points that are clearly superior to all others in the figure but not necessarily to each other.)

Now it becomes obvious that point 6 is superior to points 1, 2 and 4 since 6 provides both a higher reduction in total annoyance and lower cost. For the same reason, point 8 is superior to points 3, 5 and 7; 14 is superior to 9, 10 and 12; and 16 is superior to 11, 13 and 15.

However, the choice is not clear when one policy provides more reduction in annoyance but the other offers lower cost. For example, point 8 offers a reduction of 1,160,730 people-years-of-annoyance while 6 only offers 660,970. But 6 yields a higher economic benefit ($80.6 million v. $32.3 million). In such cases, the economic efficiency of the alternatives provides additional information.[52]

This efficiency can be computed by dividing the net cost for each option by the reduction in people-years-of-annoyance, yielding the net cost per unit of reduction. As shown in Section III, the most efficient solution for society as a whole is when the benefit of each unit of noise reduction equals its cost, i.e. when the net cost for that unit of noise reduction is zero. If the net cost per unit of noise reduction is positive, then society is paying more per unit than the noise reduction is worth. If the net cost is negative, then society is getting more benefit per unit of noise reduction than that unit costs and should be purchasing more units of reduction.

Figure VII-3 shows the efficiency of the four superior plans from Figure VII-2 as a function of the total amount of reduction in people-years-of-annoyance. To select the "best" policy from these alternatives, the goals of the society must be considered. If maximum annoyance reduction is essential and economic efficiency

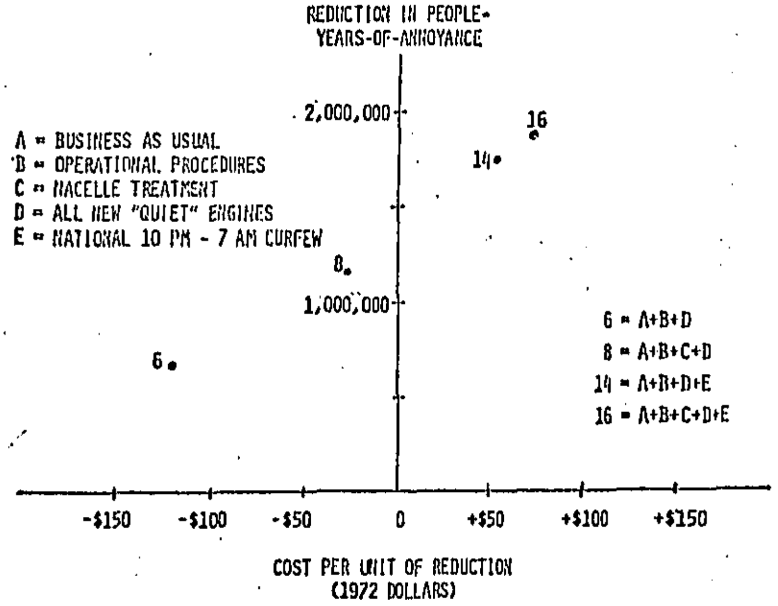

Fig. VII-3 Efficiency of the 4 Superior Noise Abatement Policy Alternatives

is secondary, then one of the policies based on a curfew would be selected: point 14 or point 16. Point 16 offers the most annoyance reduction but by such a small amount that point 14 might be the best overall solution because it is more economically efficient. If, on the other hand, economic efficiency is the primary goal and total noise reduction is secondary, then point 8 is superior since it is closest to a net cost of zero percent of noise reduction. Finally, if minimum total cost is the goal, then point 6 is the best solution for the society. But there is one further factor to consider before the options are clear.

The Cost of a Judicial Alternative

At any time, the courts could adopt a policy of allowing a recovery of noise damages by any person exposed to high noise annoyance (30 NEF or greater). The economic impact of such a decision on the region would depend on both when the decision was made and what noise abatement policies were in effect at the time.

Since an additional judicially imposed alternative would neither reduce noise nor increase property values, it would not add any benefit to the region. Rather, it would transfer benefit from the user of the air system to persons exposed to the excessive noise. It would, however, impose additional costs on the region.

The number of combinations and permutations of policy alternatives made the calculation of these costs unmanageable until some of the alternatives were eliminated. The selection process was based on maximum annoyance reduction at lower costs. The alternatives eliminated had less noise reduction and therefore would have been subject to higher court damage awards. This, in turn, would have raised their cost proportionately more than for the options selected which would involve lower court awards. Since the selected options had lower costs to start, they would therefore retain that advantage and still be superior to those alternatives deleted. Thus, no policy alternatives were overlooked by evaluating judicially imposed costs at this time.

<u>The Limited Impact of Judicial Action on Noise Levels</u> -- Before the court awards compensation, the only incentive to lower noise is the threat of a law suit and an adverse judgement. As seen in

Section V, actions brought to date have had only limited success and damages are normally small lump sums when awarded. Additional damages are only awarded if noise levels substantially increase. Therefore, the same amount of noise can continue indefinitely once compensation has been paid. Obviously, there is no incentive to decrease noise levels.

To remedy this, a "time-limited" easement has been proposed which would be based on periodic payments and periodic renegotiation of the size of the payments if noise levels change.[53] Thus the person paying the damages can reduce his liability by lowering noise levels. This approach, however, has yet to gain acceptance so calculations in this paper are based on a lump sum payment and no resulting effect on noise levels.

The Assessment of Damages -- The measure of damages normally is the difference between the property value before and after the high noise levels began. Traditionally, the amount of the damages is ascertained by the use of expert appraisers,[54] with the court often splitting the difference or using average values of the evidence introduced. Recently, however, there have been instances of the courts at least considering technical data. The Federal Court for the District of Connecticut used a geometric formula derived from an article in The Appraisal Journal[55] in a recent case.[56] In the words of the Court,

> We are dealing here with expert opinion. No opinion is necessarily conclusive. Use of this formula in an airport case, in the absence of any other pertinent data, seems to me to afford a reasonable basis for the experts' opinion....[57]

A California court has gone so far as to consider the Noise Exposure Forecast value for the property in question.[58] Although the amount of the award was not based on the actual NEF exposure, the Court did use the concept to identify which pieces of property were entitled to recovery, saying

> ...The development of the NEF contour areas provides a good means of drawing a reasonable line between those landowners who may establish a cause of action for inverse condemnation and those who may not. All landowners who suffer from substantially the same noise level are treated on an equal basis.[59]

In light of this trend, it is not unreasonable to anticipate the courts at some future date basing damages on a formula similar to that used in this paper for estimating property value changes due to noise ($200 per family unit per decibel change in NEF). Therefore, for consistency with other calculations, this formula will be used to estimate the size of potential court awards.

Potential Damage Awards -- There is no noise problem for areas where the NEF is less than 20. Therefore, calculations will be based on the amount the actual NEF exceeds 20. For NEF values between 20 and 30, damages are not substantial. Since the recoveries would be small and perhaps not even cover litigation costs, it is assumed that few actions would be brought by persons exposed to 20 to 30 NEF and the overall impact would be insignificant. It is also assumed that no one is living in an area with an NEF rating greater than 50 since these conditions would be intolerable. Therefore, the vast majority of damages awarded would go to people exposed to 30 to 50 NEF.

Of the 60,000 family units around Los Angeles International Airport exposed to 30 NEF or greater, it is estimated that 20,000 are exposed to 40 NEF or greater.[60] Assuming that the family units are distributed uniformly, it can be shown either geometrically or from the basic logarithmic formulation of the NEF measure that the average noise level per unit between 30 and 40 NEF is about 37.5 and between 40 and 50 NEF is about 47.5. The average recovery per unit would then be $3,500 ($200 x 37.5-20) for those between 30 and 40 NEF and $5,500 ($200 x 47.5-20) between 40 and 50 NEF. Multiplying these awards by 40,000 and 20,000 family units respectively, the total potential damages would be $250,000,000 1972 dollars based on the 1972 land area.

Since a uniform distribution of family units is assumed, reductions in land area exposed to these noise levels would reduce the potential size of damage awards in direct proportion. Thus the potential impact of a change in court policy in the future can be measured by multiplying $250,000,000 by the percent of the 1972 land area that would still be exposed to 30 NEF or greater at the time of the policy change.

The Impact of Damage Awards on the Region -- On the basis of the *Griggs* case,[61] it can be assumed that the damages would be assessed against the airport operator. In order to raise such large amounts of capital over a relatively short time period, the airport operator would be forced to issue bonds. The airport operator would then pass the cost of servicing these bonds on to the users of his facility and consequently to the region. Since the damage awards would be paid into the region and would eventually be recovered from the region, the awards themselves would have no net economic impact. The impact would result from the cost of the capital: the interest payments that would not have been made if the damages had not been assessed. Therefore, this interest cost is a measure of the regional economic impact of liberalized damage awards by the courts. (The income from airport bonds is normally tax exempt so they usually carry a lower interest rate than other bonds. However, since many airports probably would find themselves in the same position at the same time, they might be required to pay a higher than normal interest rate to attract enough capital. Therefore, the same 8% rate that has been used for other calculations in this analysis will be used for airport bonds.)

Since bonds normally pay simple interest, the cost to the region from the time of the damage award to 1985 could be computed by multiplying the $250,000,000 base case by the percentage of land still exposed to 30 NEF or greater (as compared to 1972) by 8% and then by the number of years until 1985.

<u>Computation of the Loss</u> -- As mentioned, the change in court policy could come at any time. If an agressive noise abatement policy is followed, there is less chance that the courts will liberalize awards. If any awards are granted, they will be small. If abatement policies are not pursued, it is more likely that the courts will act, that they will act sooner, and that there will be correspondingly higher damage awards.

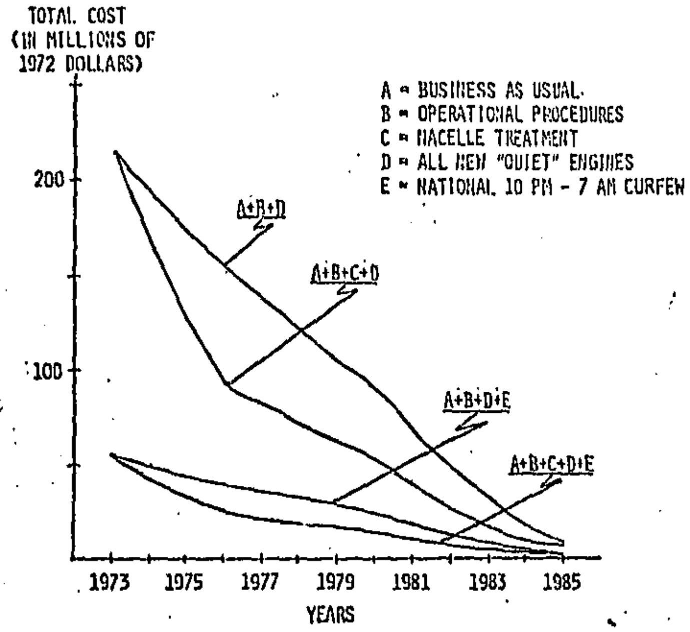

Fig. VII-4 Decrease in Maximum Potential Court Awards for the 4 Superior Noise Abatement Policy Alternatives

Figure VII-4 shows the decrease in the maximum potential amount of damages with time for the policy alternatives selected for further study. To assess the impact of these damages on area economics, three possibilities are chosen: a change in court policy occurring in 1973, in 1978 and in 1983. The Social Value Functions for the policy alternatives selected can now be recomputed to reflect the costs associated with a change in court policy in these three years (Table VII-8). Based on this information, the efficiency of the policies can be recomputed to show the effects of judicially imposed costs on the relative attractiveness of the policy alternatives.

Table VII-8

Social Value Functions for Policy Alternatives Considering Potential Judicial Costs

Policy Alternative	Non-Dollar Benefit (a)	Basic Cost (Millions of 1972 Dollars) (a)	Judicial Costs (Millions of 1972 Dollars)			Total Costs (Millions of 1972 Dollars)		
			1973	1978	1983	1973	1978	1983
SV(A+B+D)	660,970	-80.6	214.5	121.6	32.8	133.9	41.0	-47.8
SV(A+B+C+D)	1,160,730	-32.3	214.5	72.0	17.8	182.2	39.7	-14.5
SV(A+B+D+E)	1,742,000	95.5	54.6	32.0	9.0	150.1	127.5	104.5
SV(A+B+C+D+E)	1,873,000	138.5	54.6	19.2	4.8	193.1	157.7	143.3

(a) From Table VII-7

A = Business as Usual
B = Operational Procedures
C = Nacelle Treatment
D = All New "Quiet" Engines
E = National 10 p.m.-7 a.m. Curfew

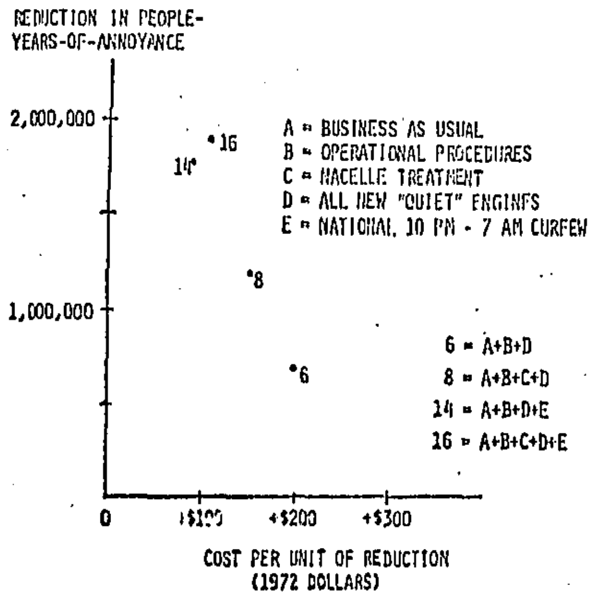

Fig. VII-5 Efficiency of the 4 Superior Noise Abatement Poicy Alternatives Including the Cost of a 1973 Court Decision

Figure VII-5 shows the results of a 1973 court decision. If the fear of such an adverse decision is imminent, there is little chance for technological change to offset the increased costs to the area. Only those policies which rely on a curfew for immediate relief (combined with longer range technological improvements) are still superior to other policy alternatives. Thus only point 14 and point 16 should be considered. Point 16 offers the maximum noise reduction, while 14 offers lowest cost and best efficiency.

If, however, an adverse judicial opinion is not expected until 1978, point 8 becomes a viable alternative (Figure VII-6).

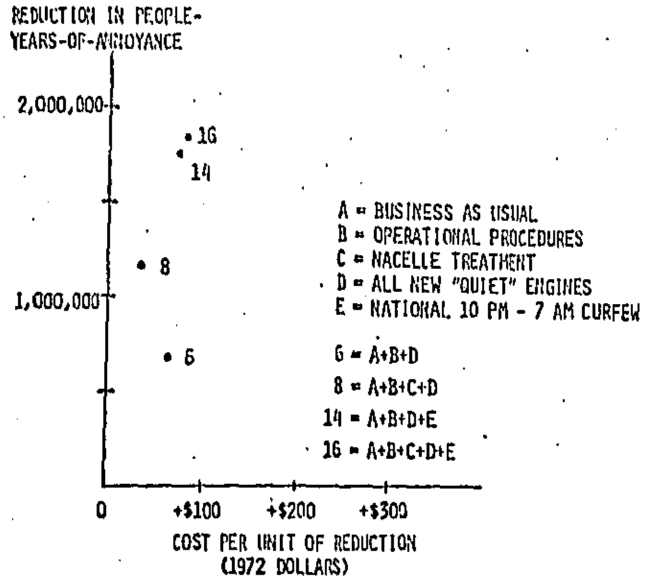

Fig. VII-6 Efficiency of the 4 Superior Noise Abatement Policy Alternatives Including the Cost of a 1978 Court Decision

Within this time frame, acoustic treatment of the nacelles offers somewhat competitive noise reduction to a curfew. If the social goal is maximum annoyance reduction, then either point 14 or 16 offers a better alternative, with 16 being best. If efficiency or lower cost is the primary goal, then point 8 should be the choice. Since points 8 and 16 both incorporate the same technological change (Business as Usual plus Operational Procedures plus Nacelle Treatment plus New Quiet Engines), the basic choice is whether the additional benefits of a curfew (712,000 people-years-of-annoyance) offset its greater basic cost ($170,000,000 without judicial costs).

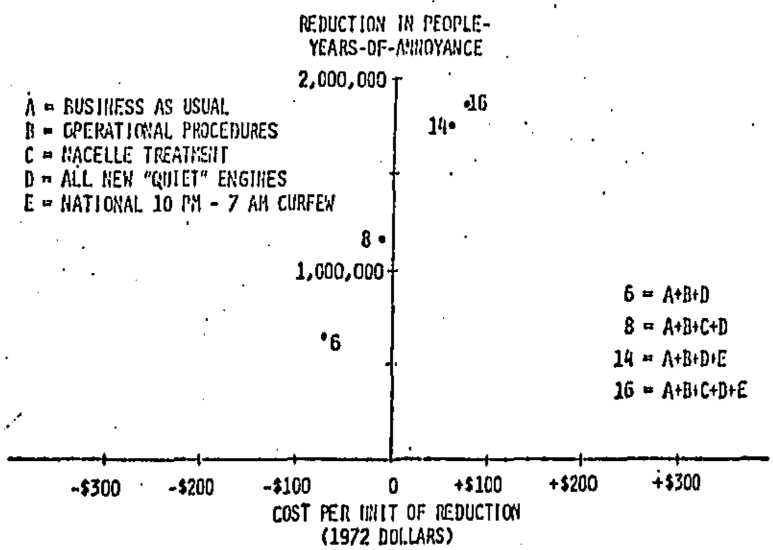

Fig. VII-7 Efficiency of the 4 Superior Noise Abatement Policy Alternatives Including the Cost of a 1983 Court Decision

Finally, if the adverse judicial decision is not expected until 1983, point 6 must also be considered since it yields the highest dollar benefit to the area (Figure VII-7). However, point 16 still offers the greatest noise reduction and point 8 the best efficiency while providing a moderate level of noise reduction.

Summary of Social Value Function Analysis

The Social Value Function computations reduce the number of acceptable policy alternatives from 16 to 4. When the effects of potential damage awards that could be imposed by the courts are considered, the selection of the optimum solution from among these four alternatives depends on when the court award occurs.

If an adverse judicial decision is expected in the near future, the most effective strategy is the imposition of a curfew immediately, while also seeking a long-term technological solution. Over greater time periods, the relative merits of a curfew decrease as technology lowers the overall level of annoyance.

All four of the potentially acceptable alternatives contain at least the following policy options:

A = Business as Usual allowing for the gradual replacement of older noisy aircraft

B = Operational Procedures using a $6^{\circ}/3^{\circ}$ glide slope on landing

D = All New "Quiet" Engine combined with an all new aircraft designed around the engine to provide even greater noise relief upon its introduction in 1980.

Therefore, these common options should be actively encouraged or required no matter which overall policy alternative is chosen.

Whether the additional options of nacelle treatment or curfew or both should be required as well is a difficult decision which must be based on the relative value to the society of maximum noise reduction, economic efficiency or lowest social cost. These values may vary depending on the time frame and locality in question. Since the decision depends on social values, the choice is most appropriately made through the political process.

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VIII. EVALUATION AND RECOMMENDATIONS

Based on the Social Value Function analysis, both the adoption of operational noise abatement procedures and the development of an all new quiet engine on all new aircraft should be implemented as policy alternatives for reducing noise in the vicinity of airports. Since both alternatives affect the aircraft, an instrument of interstate commerce, they should be adopted at the national level.

Whether nacelle treatment, curfew or both should also be required is a political issue based on the value society places on low cost and economic efficiency on the one hand and maximum annoyance reduction on the other. The resolution of this issue may be affected not only by the political climate but also by the judicial attitude toward damage awards in any given region. If large awards are imminent, a curfew is the only policy alternative that can offer offsetting noise reduction in the near future. If the threat of court action is remote, however, it is no longer clear whether a curfew justifies its cost.

The top 15 airports in the nation account for an estimated 50% of those operations that would be affected by a curfew.(1) In the rest of the country, a curfew would have little impact since not many night flights occur anyway. Consequently, for the nation as a whole, nacelle treatment would seem to be a better policy alternative than a national curfew. Since the treatment would be made on all the aircraft in the fleet, its benefits would accrue to anyone who lives near any airport, not just to those in high noise areas.

A curfew can be useful in particular areas, however, as the analysis of the Los Angeles region shows. In regions that are highly industrialized and need air service but have acute noise problems, the curfew could be a powerful tool for controlling damage awards and the consequent economic impact on the region. Likewise, limited condemnations or soundproofing programs could also be effective at a particular airport even though their cost would prohibit national application. Thus it would seem that, in addition to national programs, local authorities should be able to adopt their own noise abatement plans tailored to their own specific needs. This raises the problems of multiplicity of standards and conflicting local and federal jurisdictions.

To avoid these difficulties, a plan has been proposed that would combine federal powers with local flexibility.(2) In addition to setting noise standards for aircraft, the federal government would also set minimum standards for community noise exposure (as has been done on other federal programs). For example, the U. S. Department of Housing and Urban Development has announced that

> It is HUD's general policy to foster the creation of controls and standards for community noise abatement and control by general purpose agencies of State and local governments, and to support these activities by minimum national standards by which to protect citizens against the encroachment of noise into their communities and places of residence.(3)

In addition to minimum standards, two or three other decreased levels of community noise exposure would also be proposed. The local government, working with the airport operator (as in the California Plan discussed in Section VI) would be allowed to impose any one of the additional standards specified by the federal government if the minimum standards were not felt sufficient for the region.

As in the California Plan, the federal government would enable the airport operator to comply with the standards by making several local policy alternatives available (imposition of curfew, capacity limitations, land purchases, etc.). This would allow the operator to select those options best suited to his own location in terms of both noise reduction and economic impact.

Since the federal government sets the standards, any conflict between local and federal powers is eliminated. There are only a few standards to consider so the airlines are not faced with the problem of each and every locality developing different rules and regulations totally independently of each other. Thus the impact on the air system is less.

The plan also involves the local community in the airport planning process. This involvement has been held essential to future development and growth of airports and, consequently, the air transportation system.[4] In addition to noise reduction, such a plan would open new channels of communication between the developers of the air system and the community. The resulting mutual understanding of the problems and objectives of both sides could break the planning deadlock and permit rational development of new or expanded airport facilities in the region.

In summary, the federal government should require operational changes and encourage the development of new quiet engines and aircraft by imposing higher standards of noise reduction over a period of time. In addition, nacelle treatment should be required on present aircraft. The longer this treatment is delayed, the more its effectiveness is reduced as all new aircraft eventually enter service and replace present planes.

Local participation is also essential to solve particular problems in particular places. To settle issues of constitutionality once and for all, the federal government should preempt the field of regulating noise exposure around airports. However, a large portion of this control should be redelegated to the local community once the standards are set and the scope of participation defined at the federal level.

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APPENDIX A

Noise Measurement

Noise measurements can be classified into three types:

1. those used to measure noise levels at a given point from a single aircraft operation;
2. those used to measure noise exposure at a given point over time from a number of aircraft operations; and
3. those used to measure noise impact over time throughout the community from a number of aircraft operations.[1]

In this paper, perceived noise level (L_{PN} or PNdb) and effective perceived noise level (L_{EPN} or EPNdb) are used as single event measurements. Both are measurements of the pressure level of the sound with respect to a reference pressure and are in decibel units which are measured logarithmically. As a result, some caution must be used when comparing different sound levels. For example, if a single aircraft flyover has a rating of x decibels, two simultaneous aircraft flyovers have a rating of x + 3 decibels, not 2x. Mathematically, this can be seen as follows:

If n is the relative sound pressure level of a single noise, then the noise level (x) in decibels is

$$x = 10 \log n \ .$$

If two sounds of n pressure level occur simultaneously, then

$$y = 10 \log 2 n \ .$$

But $$10 \log 2n = 10 \log n + 10 \log 2$$

$$= x + (10 \times .3010)$$

$$\cong (x + 3)\text{db} .$$

The perceived noise level measurement places varying weights on the frequency of the sound to compensate for the sensitivity of the human ear to different tones. High frequency components of the sound are given heavier weight than low frequency components.[2] In addition, the effective perceived noise level adds a correction for the duration of the sound as well as its frequency characteristics.[3] The effective perceived noise level is the technique used under the Federal Aviation Regulation's Part 36 which specifies maximum noise levels for aircraft operations.

In general, perceived noise levels are used in this paper where an objective measurement or comparison of the magnitude of different sound events is made. Effective perceived noise levels are used where subjective reactions are being studied.

The Noise Exposure Forecast (NEF) technique is used for the second class of measurement since it incorporates the number of aircraft operations and their time of day. As the technique is based on the use of effective perceived noise levels for individual events, NEF is also a logarithmic measurement.

The first attempt to compensate for the effects of the number and time of day of aircraft operations was the Composite Noise Rating (CNR) developed in 1952.[4] However, it was based on the perceived noise level scale. With the proposed use of effective perceived noise level for federal aircraft standards, a new measure was needed. This led to the development of the Noise Exposure Forecast. NEF is defined as

$$NEF = 10 \log \sum_j \text{antilog} \frac{NEF_j}{10}$$

where $NEF_j = (L_{EPN})_j + 10 \log \left[(N_D)_j + 16.67(N_N)_j\right] - 88$

computed for a single type of aircraft (j) producing a specific noise characteristic; and

$(L_{EPN})_j$ = the specific noise characteristic for aircraft type j

$(N_D)_j$ = number of day (7 a.m. to 10 p.m.) operations of j type aircraft

$(N_N)_j$ = number of night (10 p.m. to 7 a.m.) operations of j type aircraft

88 = scalar value used to produce a number that will not be confused with a CNR computation.[5]

One night flight produces the same amount of annoyance as 16.67 day flights in this computation.

Community response to NEF levels can roughly be correlated as follows:

NEF less than 20	No noise problem.
NEF between 20 and 30	Some noise complaints are possible and noise may interfere with some activities.

NEF between 30 and 40	Individual reaction may include vigorous repeated complaints and concerted group action. Construction of homes, schools, churches and other noise sensitive land uses should not be undertaken without detailed analysis.
NEF greater than 40	Serious problems are likely. No land uses or construction should be considered without complete analysis.[6]

For the third type of measurement used to compute noise impact over time throughout the community, people-years-of-annoyance will be used. It can be shown that, assuming a uniform population density, the number of people exposed to a given level of annoyance is proportional to the land area within a given noise level contour.[7] If the land area decrease is multiplied by the average population density, the resulting reduction is proportional to the reduction of people annoyed. If this is further multiplied by the number of years the reduction exists, it becomes a measure of the reduction of community annoyance over time.[8]

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APPENDIX B

The Relationship Between Change in Decibels and Change in Area

Assume a source sound pressure level L and sound pressure levels L_1 and L_2 at distances R_1 and R_2 from the source, all with respect to a reference sound pressure level of L_0. Measured in decibels, these units would be

$$X(db) = 10 \log \frac{L}{L_0}$$

$$X_1(db) = 10 \log \frac{L_1}{L_0}$$

$$X_2(db) = 10 \log \frac{L_2}{L_0} .$$

Now $$10 \log \frac{L_1}{L_0} = 10 \log L_1 - 10 \log L_0 \text{ , and}$$

$$10 \log \frac{L_2}{L_0} = 10 \log L_2 - 10 \log L_0 .$$

Therefore $$X_1 - X_2 = 10 \log L_1 - 10 \log L_2 \text{ , or}$$

$$\Delta \, db = 10 \log \frac{L_1}{L_2} .$$

Assuming a spherical distribution

$$L_1 = \frac{L_0}{R_1^{\ 2}} \text{ , and}$$

$$L_2 = \frac{L_0}{R_2^{\ 2}} .$$

So $$\Delta db = 10 \log \frac{\frac{L_0}{R_1^2}}{\frac{L_0}{R_2^2}}$$

$$= 10 \log \frac{L_0}{R_1^2} \times \frac{R_2^2}{L_0}$$

$$= 10 \log \frac{R_2^2}{R_1^2} .$$

Now $$Area_1 = \pi R_1^2$$

$$Area_2 = \pi R_2^2 .$$

So $$R_1^2 = \frac{Area_1}{\pi}$$

$$R_2^2 = \frac{Area_2}{\pi} .$$

So $$\Delta db = 10 \log \frac{R_2^2}{R_1^2} = 10 \log \frac{\frac{Area_2}{\pi}}{\frac{Area_1}{\pi}}$$

$$= 10 \log \frac{Area_2}{\pi} \cdot \frac{\pi}{Area_1}$$

$$= 10 \log \frac{Area_2}{Area_1} .$$

Therefore, if the ratio of areas is known, the change in decibels is

$$\Delta db = 10 \log \frac{Area_2}{Area_1} .$$

Conversely, the area ratio can be determined if the change in decibels is known:

$$\frac{Area_2}{Area_1} = \text{antilog}\left(\frac{\Delta db}{10}\right)$$

The relationship between area and changes in noise level is graphically shown in Figure B-1.

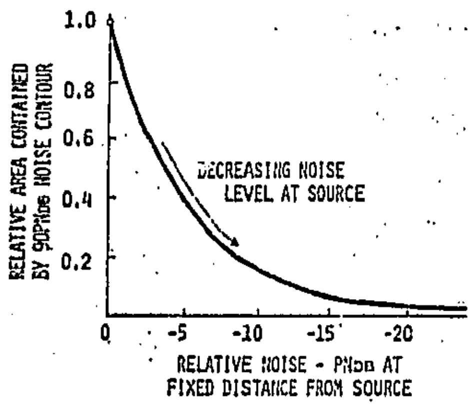

Fig. B-1 Effect of decreasing noise on area

APPENDIX C

NEF Reduction Resulting from a 10 p.m. to 7 a.m. Curfew

If N_T equals the total number of aircraft operations and P the fraction of the total that occurs at night, then

$$NEF(present) = L_{EPN} + 10 \log \left[N_T (1-P) + \frac{50}{3} N_T P\right] - 88 .$$

If the fleet mix is assumed constant so that L_{EPN} remains the same and if all flights banned by a curfew are shifted to day operations so that N_T is constant, then

$$NEF(curfew) = L_{EPN} + 10 \log N_T - 88 \text{ , and}$$

$$NEF(present) - NEF(curfew) = 10 \log \left[N_T (1-P) + \frac{50}{3} N_T P\right] - 10 \log N_T .$$

$$\text{Now} \quad \left[N_T (1-P) + \frac{50}{3} N_T P\right] = N_T \left[(1-P) + \frac{50}{3} P\right]$$

$$= N_T \left[1 - P + 16.66P\right]$$

$$= N_T \left[1 + 15.66P\right]$$

$$\text{so} \quad 10 \log \left[N_T (1-P) + \frac{50}{3} N_T P\right] = 10 \log \left[N_T (1 + 15.66P)\right]$$

$$= 10 \log N_T + 10 \log (1 + 15.66P)$$

$$\text{Now} \quad NEF(present) - NEF(curfew) = 10 \log N_T + 10 \log (1 + 15.66P) - 10 \log N_T$$

$$= 10 \log (1 + 15.66P) .$$

For appropriate values of P, the change in NEF can now be computed (Table C-1).

Table C-1

Change in NEF with Respect to the Fraction of Night Operations

Fraction	Change in NEF
.1	-4.09
.15	-5.25
.2	-6.16