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ENVIRONMENTAL IMPACT STATEMENT
REVIEW GUIDELINES
FOR
AIRPORT/AIRCRAFT NOISE

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for

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INSTRUCTIONS FOR USE AND INTERPRETATION
OF SECTION I
"AIRCRAFT NOISE MEASUREMENT TECHNIQUES AND IMPACT EVALUATION CRITERIA"

The individual reviewing the aircraft noise component of an E.I.S. should have a working knowledge of the various approaches used in estimating aircraft noise emissions from single events (individual aircraft) and cumulative exposures (several or many aircraft.) Although the Environmental Protection Agency has officially taken the position that all new aircraft noise impact analyses should employ the Ldn/Leq methodology, it is likely that a considerable interval of time will elapse before the currently existing and rather extensive data bases in CNR, NEF and CNEL may be converted. Undoubtedly, many actions requiring an E.I.S. will generate such small incremental changes in the noise environment that the expense of reprogramming to accommodate the Ldn/Leq methodology will not be warranted.

An adequate understanding of the most frequently used aircraft noise impact evaluation criteria and methodologies may be obtained by relating Table I and Figure A to indicated sections in the text addressing objectives, significant advantages and disadvantages and definitions and examples.

Table I briefly depicts the applicable objectives and rationale for twelve measurement units. In the box created by the intersection of a row corresponding to a measurement unit and a column indicating objective or rationale, appears the appropriate criteria and/or formula for obtaining the measurement units, followed by a letter denoting an explanitory illustration and page numbers keyed to discussions, definitions, and examples in the text.

Figure A graphically depicts the relationship between composite measures of annoyance and their respective single event sound levels as a function of the number of operations experienced and the time of day during which they occur.

Measurement Unit	(A) Sound Pressure Level	(B) Weighting Frequency (HZ) to approximate human auditory experience	(C) Correcting for the Duration of Overflight
dB	.0002 dynes per sq. CM 7, B, C		
dBA		A-weighted decibels 7, B	
PNdB		D-weighted decibels 7, B	
SEL			Time integrated average dBA from 10dB downpoints 10, A, D, E
SENEL			Time integrated average dBA from 30dB downpoints 10, A, D
EPNdB			Time integrated average pNdB from 10dB downpoints 11, A, B, E J-Q
CNR			
NEF			
Leq			
Ldn			
CNEL			
FI			
NU			

TABLE I

surement Unit ont'd)	(D) Correcting for Pure Tones	(E) Correcting for the Number of Operations	(F) Correcting for Night Operations: Each Night OP = X Day OPS
dB			
dBA			
PNdB			
EL			
ENEL			
PNdB	Penalty for "spikes in sound spectrum 11, A, C		
NR		Equals PNdB + 10 Log N - 13 14, 20, A	X = 16.67 10 PM - 7 AM 14, 20, A
EF		Equals EPNdB + 10 Log N - 88 15, 20, A	X = 16.67 10 PM - 7 AM 15, 20, A
eq		Equals SEL + 10 Log N - 10 Log T 15, 16, 54, A	
dn		Equals SEL + 10 Log N - 49.4 16, A, 21	X = 10 10 PM - 7 AM 16, 21, A
NEL		Equals SENEL + 10 Log N - 49.4 16, 17, A, 21	X = 10 10 PM - 7 AM 16, 17, 21, A
I			
U			

TABLE I (cont'd)

Measurement Unit (Cont'd)	(G) Correcting for Evening Operations: Each Evening OP = X Day OPS	(H) Evaluating Relative Effect on the Individual	(I) Evaluating Relative Effect on Large Populations
dB			
dBA			
PNdB			
SEL			
SENEL			
EPNdB			
CNR			
NEF			
Leq			
Ldn			
CNEL	X = 3 16, 17, 21, A 7 PM - 10 PM		
FI		Emission Level - 22, 54 Background or Criterion Level - 20	
NU			Effected POP x 24, 54 Fractional Impact

TABLE I (Cont'd)

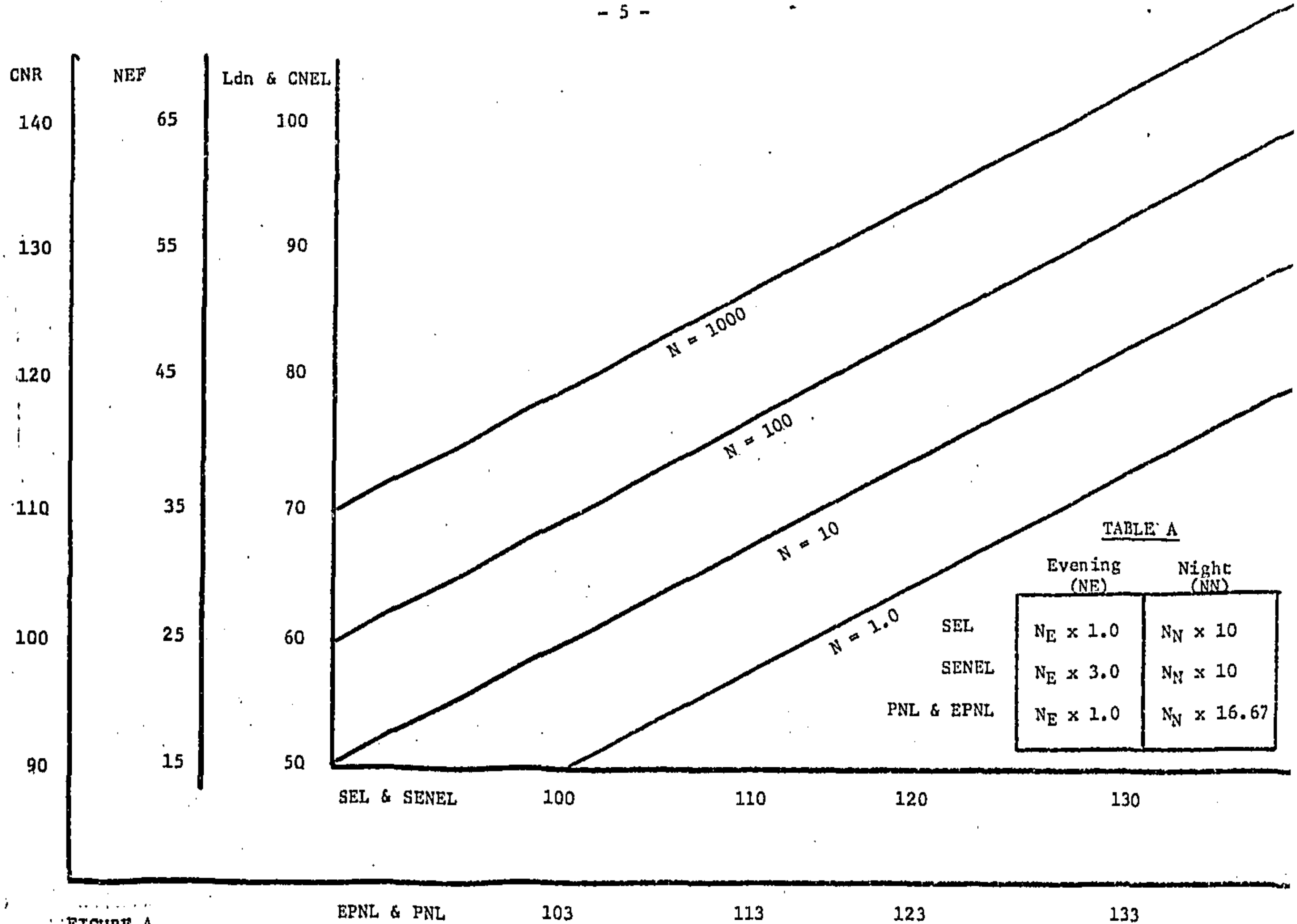


TABLE A

	Evening (NE)	Night (NN)
SEL	N_E x 1.0	N_N x 10
SENEL	N_E x 3.0	N_N x 10
PNL & EPNL	N_E x 1.0	N_N x 16.67

FIGURE A

1. To obtain N (total operations), add to day operations (7 AM - 10 PM) adjusted evening (7 PM - 10 PM) and night (10 PM - 7 AM) operations from Table A, above.
2. Composite measures and single event values may not be equal - see explanitory note.

* NOTE: The values indicated for CNR, NEF, Ldn, and CNEL may be obtained only for the respective values of PNL, EPNL, SEL and SENEL. This does not mean that the observed values at a fixed reference point will be equivalent for a given airport, flight track or aircraft, e.g. a point 4000 feet from a flight tract may measure 103 EPNdB for a given operation, but will not necessarily (and almost certainly will not) measure 100 SEL for a given overflight. The analyst should be aware that D-weighted (EPNdB) and A-weighted (SEL) sound level meters will depict different rates of atmospheric absorption as a function of distance, depanding on the noise spectrum emitted by individual aircraft. Hence, it is not possible to state, for example, that a 45 NEF contour is "the same as" the 80 Ldn contour. However, because of similarities in weighting mechanisms the following comparisons are suitable for impact evaluation and planning purposes:

CNR = NEF + 75
Ldn = CNEL

DEFINITIONS AND EXAMPLES

Frequency = cycles per second (CPS), or HERTZ (HZ), i.e., the number of sound waves striking a surface in one second. Auditory experience is pitch or tone, denoting high or low notes in music. Common range is 62.5 to 16,000 CPS.

Sound Pressure Level = the energy in each sound wave as it strikes a surface, i.e., the amplitude of the wave, which is measured in decibels (dB). Auditory experience is loudness. Sound pressure varies logarithmically as follows:

$$SP = 10^{n/20}$$

where

SP is sound pressure in dynes per square centimeter and n is the change in decibels

Thus, when comparing two sound pressure levels, the smaller numerical value may be subtracted from the larger and the difference substituted for 'n'.

Example: How much more sound pressure has 80 than 60 dB?

$$\begin{aligned} SP &= 10^{n/20} \\ &= 10^{80-60/20} \\ &= 10^{20/20} \\ &= 10^{1} \\ &= 10 \text{ times the pressure} \end{aligned}$$

Example: How much more sound pressure has 100 than 60 dB?

The answer should be 100 times the pressure.

Loudness = human auditory response to combinations of frequency and sound pressure level. In order to measure loudness, instruments must be calibrated to respond to sound in a manner approximating the human auditory experience. In the United States, two weighting systems predominate, the "A" scale (dBA) and the "D" scale (dBD and PNL expressed as PndB), as depicted in Figure B.

Spectrum or Signature = depiction of sound with simultaneous consideration of frequency (HZ) and sound pressure levels, such that sound pressure levels are indicated for various frequencies. In Figure C, note the acute variation in sound pressure between 1500 and 4000 CPS. Such variations are referred to as "pure tones" or "spikes" in the signature.

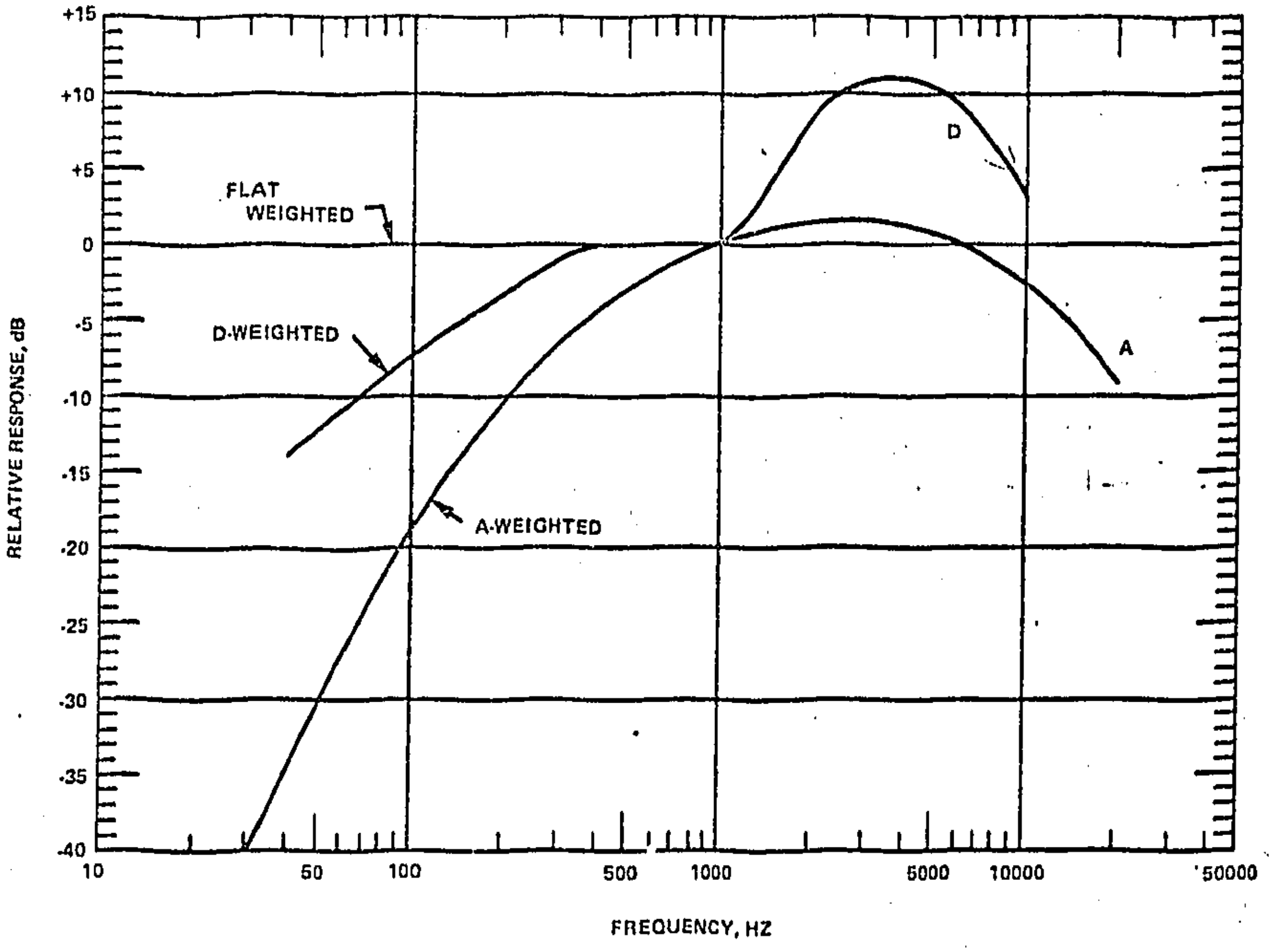


FIGURE B COMPARATIVE RESPONSE OF NOISE WEIGHTING NETWORKS.

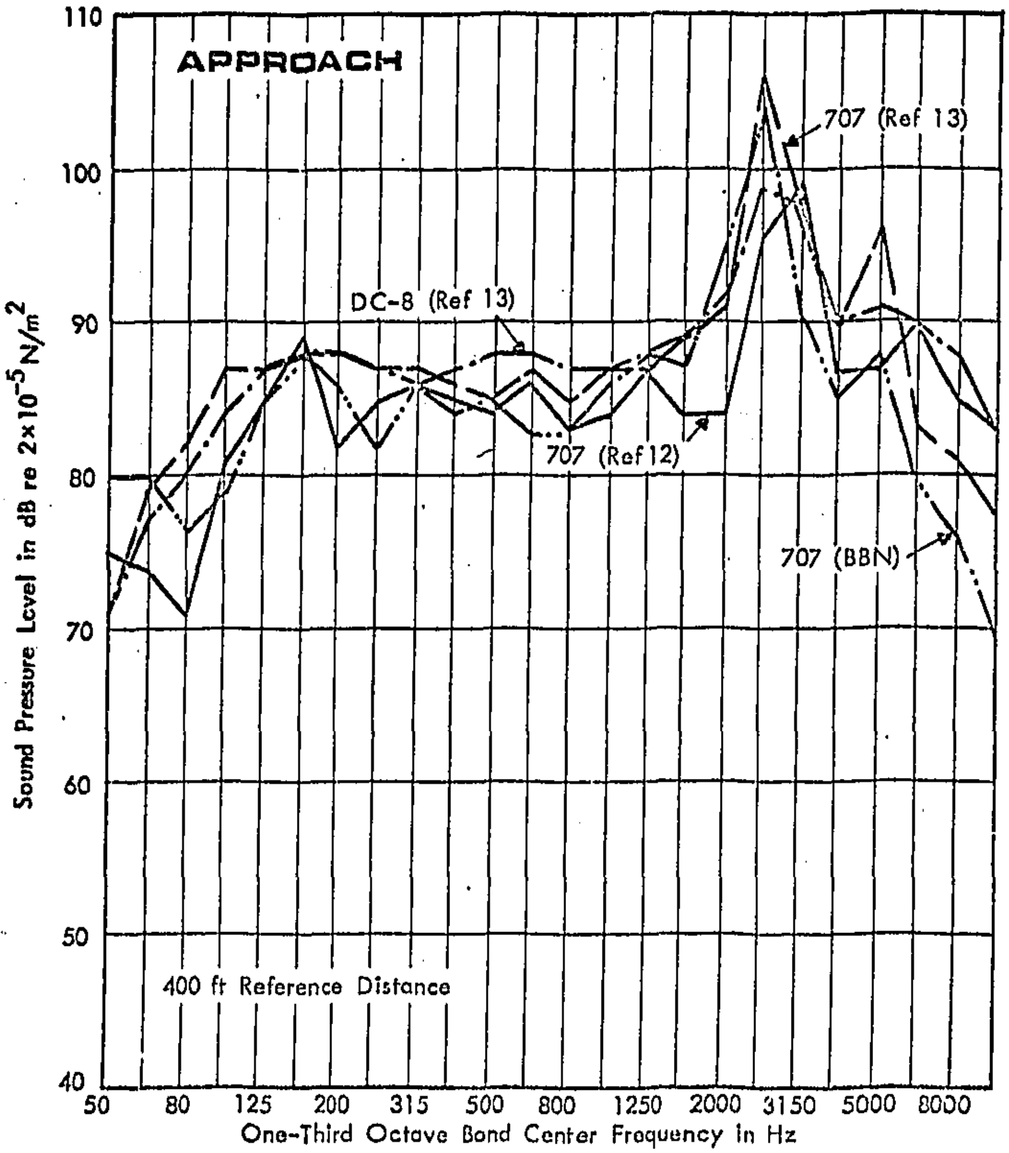
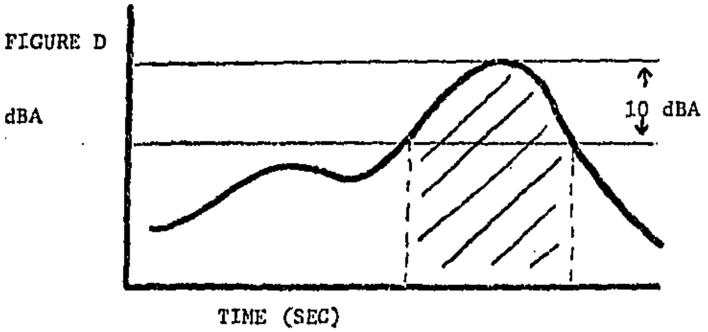


FIGURE C NOISE SPECTRA FOR DEVELOPMENT OF EPNL VS DISTANCE CURVES - DC-8 AND 707 APPROACH

Sound exposure Level = SEL. As a single overflight by an aircraft is experienced, loudness varies during the duration of the exposure. A typical exposure might be recorded as follows:

FIGURE D



The first "hump" is caused by fan noise as the aircraft approaches the observer, while the "trough" occurs as it passes and the observer is shielded by the engine coulings. The second "hump" occurs as the aircraft passes, and the exaust roar predominates. Although different frequencies dominate during each peak, the "A" weighting adjusts to approximate loudness as a human would perceive it. The significant portion of the exposure period, where SEL is utilized, is indicated by the time period beginning 10 dBA before the highest peak and ending 10 dBA after it. (Such points are often called the 10 dBA "down points.") A time integrated average sound level is then determined for this period.

SENEL = sound equivalent noise exposure level, is used in the State of California, and differs from SEL in that 30 dBA down points are prescribed.

EPNL = effective perceived noise level, is expressed as EPNdB. 10 dB down points are utilized, but the measurement units are PNdB, i.e., are "D" weighted and more responsive to high frequencies. An additional penalty is prescribed for pure tones or "spikes" in signatures. Aircraft are certified for noise by the F.A.A. utilizing EPNdB.

Atmospheric absorption, often characterized by an "absorption coefficient" for a given frequency for such atmospheric variables as temperature and humidity, is a critical factor in forecasting aircraft noise exposure levels, and the reason for many of the basic incompatibilities between EPNL (EPNdB) and SEL (dBA). A tone with a frequency of 8000 CPS will be absorbed or will "attenuate" 55 dB for every 1000' from the source at a temperature of 10° F and 10% humidity. This indicates that at a distance of 3000' the 8000 CPS shriek of jet turbines measuring 150 dB at 100' would be inaudible. In general, high frequency tones have higher absorption coefficients than low tones. Thus, low tones "carry" a greater proportion of their original sound pressures than lower tones. Because A and D weighted sound level meters respond quite differently to identical signatures (the former greatly supressing tones below 500 CPS and the latter greatly accentuating tones in the 1000 - 4000 CPS range), and signatures may change considerably as a function of distance, temperature and humidity, it is not practical to convert sound levels measured in dBA to PNdB or vice versa. The rule of thumb that PNdB = dBA + 13 could be accurate for a signature for a given aircraft engine at a specified distance, temperature and humidity, but the absorption coefficients for identical engines will vary significantly depending on whether dBA or PNdB is employed as a measurement criteria.

Similarly, it is not practical to convert SEL to EPNL with any fixed constant because the respective A and D weighting mechanisms are utilized. In general, all jet aircraft on approach, and older 4-engine aircraft on takeoff will have signatures causing this complication (See Figure E). However, preliminary modeling exercises indicate that for DC-9, 737, and 727 aircraft in the takeoff mode, SEL may be closely approximated by EPNL -3, provided the reference point is more than 1000' from the aircraft.

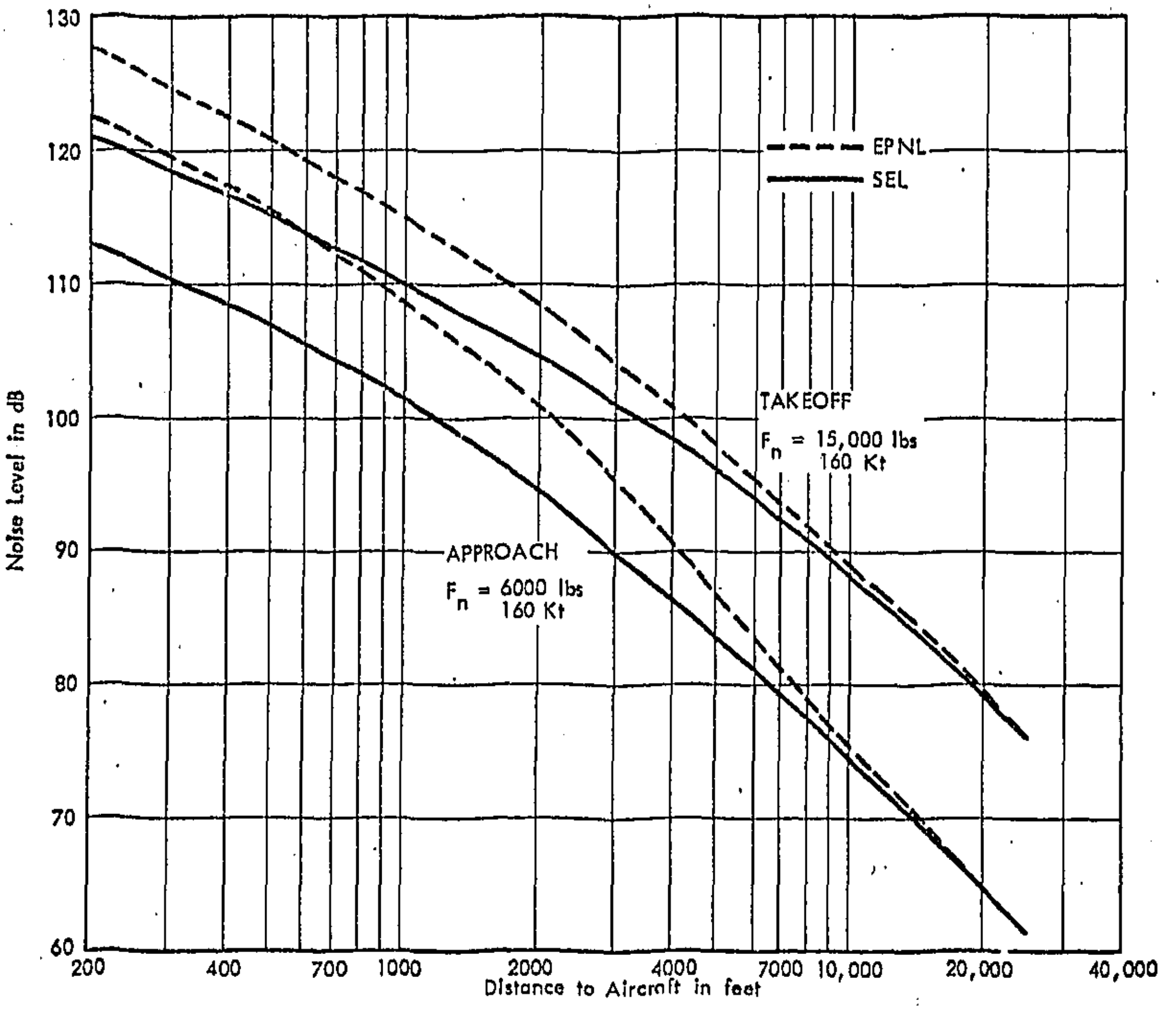


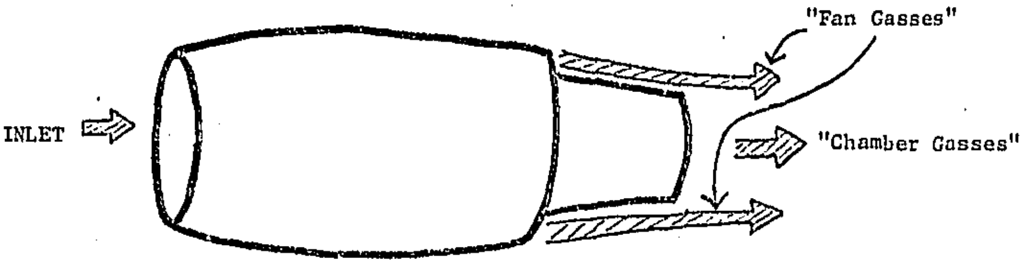
FIGURE E COMPARISON OF SEL AND EPNL VARIATIONS WITH DISTANCE - 707 AND DC-8 TRANSPORT AIRCRAFT WITH JT3D SERIES ENGINES

Note that the point of intersection does not imply equivalent sound levels, but equal rates of absorption.

Standard Day = used to describe average atmospheric conditions for a 24 hour period, e.g., 70% humidity and 50° F for aircraft certification purposes.

By-Pass Ratio = the ratio of the volume of exaust gases ejected from the main conbustion chamber to those ejected by the larger "fan" turbine blades in turbo jet engines.

FIGURE F



The higher the ratio, the lower the sound pressure level for a given thrust application, because the incremental velocity between air flowing past the engine and the driving thrust is smaller. High bypass ratio engines have been developed to generate greater thrust at takeoff speeds and to meet F.A.A. Part 36 Noise Regulations, and include extensive accoustical insulation of nacelles (engine coulings), and may be observed on the new "wide body" series of jets, e.g., DC-10, 747 (CF6 or JT9D), and Lockheed 1011 (Rolls Royce powered) aircraft. Dominant frequencies are much lower than with low by pass ratio engines, and net reductions of up to 18 EPNdB are obtained over previous jet aircraft.

Aircraft Classification = the jet fleet may be conveniently grouped into broad classes by number and type of engines and "stage length", a criterion employed in approximating adjustments in gross take-off weight as follows:

TABLE II

TYPES	ENGINES; HIGH & LOW BY-PASS	TRIP LENGTH IN MILES 0-500	0-1000	2-2000	3000
DC-9, 737	2 eng. LBPR				
727-100, 727-200	3 eng. LBPR				
707, 720, DC-8	4 eng. LBPR				
DC-10, L1011	3 eng. HBPR				
747	4 eng. HBPR				

The higher the gross takeoff weight, i.e., the longer the stage length, the lower and louder the aircraft will be during takeoff for a given power setting. Thus, low by-pass ratio powered aircraft with short stage lengths will tend to be the quietest.

Load Factor = simply the % of seats which are occupied by passengers during an operation. Load factors and capacities determine the number of operations which are necessary to accommodate a given number of enplanements, as well as gross takeoff weights.

CNR = composite noise rating, a methodology designed to predict community annoyance as a function of frequency of exposure, sound level (PNdB), and time of day as follows:

$$CNR = PNdB + 10 \text{ Log } (N_D + 16.67\ N_N) - 13$$

where:

PNdB is the "average" peak flyover noise
N_D is the number of operations occurring between 7 AM and 10 PM and,
N_N is the number of operations occurring between 10 PM and 7 AM.

Example:

$PNdB = 103$
$N_D = 500$
$N_N = 65$

$$\begin{aligned} CNR &= 103 + 10 \text{ Log } (500 + 16.67 \times 65) - 13 \\ &= 103 + 10 \text{ Log } (1583) - 13 \\ &= 103 + (10 \times 3.2) - 13 \\ &= 135 - 13 \\ &= 122 \end{aligned}$$

NEF = Noise Exposure Forecast, and differs from CNR only in that it utilizes EPNdB, rather then PNdB to make additional corrections for the duration of the overflight and "pure tones" (spikes in the noise signature), while employing a larger constant (-88 vs. -13):

$$NEF = EPNdB + 10 \text{ Log } (N_D + 16.67 N_N) - 88$$

where:

EPNdB is the time integrated value for the "average" overflight noise exposure
N_D is the number of operations occurring from 7 AM to 10 PM, and
N_N is the number of operations occurring from 10 PM to 7 AM.

Example:

EPNdB = 103
N_D = 500
N_N = 65

NEF = 103 + 10 Log (500 + 16.67 x 65) - 88
= 103 + 10 Log (1583) - 88
= 103 + (10 x 3.2) - 88
= 135 - 88
= 47

Leq = Equivalent Sound Level; the "average" sound level for a given time period, or the constant sound level which would give the same sound energy as one which varies with time for some time period. It may be derived from Sound Exposure Level (SEL) by subtracting 10 times the common logarithm of the duration of the time period in seconds accounting for the constant of -49.4 employed in the Leq formula for a 24 hour period:

$$Leq_{24} = SEL + 10 \text{ Log } N - 49.4$$

where:

Leq_{24} is the average sound level for a 24 hour period
SEL is the time integrated average sound level during each operation, and
N is the number of operations in the 24 hour time period.

Note that 24 hours = 86,400 seconds and that 10 Log 86, 400 = 10 x 4.936 or 49.4. Thus, for a given time period, i.e., Ld (day), Ln (night) Lh (hour), it is convenient when addressing aircraft noise to employ the following formula:

$$Leq = SEL + 10 \text{ Log } N - 10 \text{ Log } T$$

Where T is the time of the period in question in seconds.

Thus, when estimating the Leq for one hour (Ln) for a given flight track with 30 operations and an SEL of 85dB per operation, the analyst could compute:

Lh = SEL + 10 Log N - 10 Log T

or

Lh = 85 + 10 x Log 30 - 10 Log 3600
= 85 + 14.8 - 35.6
= 64.2

This indicates that a constant sound level of 64.2 dBA would yeild the same sound energy over a one hour period as 30 overflights at 85 SEL.

Ldn = Average day/night sound level, and utilizes dBA, time integrated from 10 dB "downpoints" to obtain SEL as the basic single event input, while weighting "night" operations by a factor of 10, rather than 16.67. Here, the constant selected is - 49.4.

$$Ldn = SEL + 10 \text{ Log } (N_D + 10 N_N) - 49.4$$

where:

SEL is the time integrated value for the "average" overflight in dBA,
N_D is the number of operations occurring between 7 AM and 10 PM
N_N is the number of operations occurring between 10 PM and 7 AM.

Example:

SEL = 100
N_D = 500
N_N = 65

Ldn = 100 $\pm$ 10 Log (500 + 10 x 65) - 49.4
= 100 $\mp$ 10 Log (1150) - 49.4
= 100 + (10 x 3.06) - 49.4
= 100 + 30.6 - 49.4
= 130.6 - 49.4
= 81.2

CNEL is almost identical to Ldn, except the single event input, SENEL is measured from 30 dB "downpoints" rather than 10 dB, and an additional weighting of 3 is used as a multiplier for flights occurring during the "evening".

$$CNEL = SENEL + 10 \text{ Log } (N_D + 3\ N_E + 10\ N_N) - 49.4$$

where:

SENEL is the time integrated value of the sound level emitted from the average overflight in dBA, measured from the points 30 dB preceding and 30 dB following the peak sound level obtained.

N_D is the number of operations occurring between 7 AM and 7 PM
N_E is the number of operations occurring between 7 PM and 10 PM
N_N is the number of operations occurring between 10 PM and 7 AM

Example:

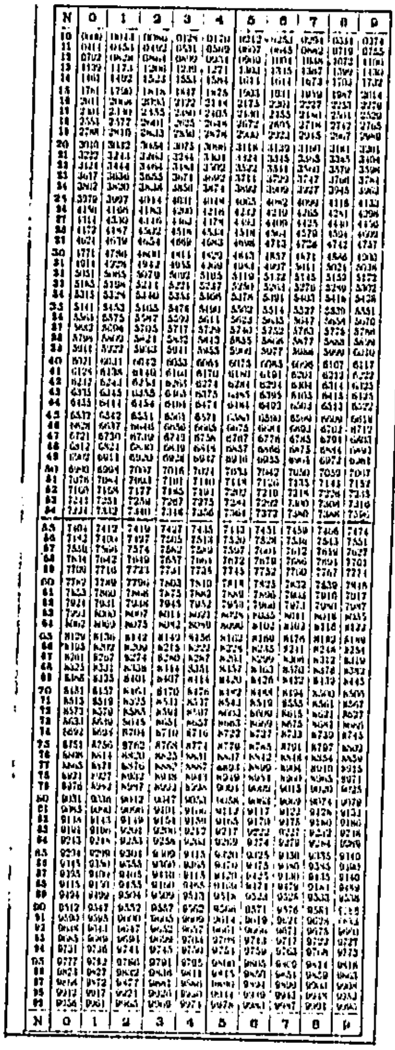
$SENEL = 100$
$N_D = 450$
$N_E = 50$
$N_N = 65$

$$\begin{aligned} CNEL &= 100 + 10 \text{ Log } (450 + 3x50 + 10x65) - 49.4 \\ &= 100 + 10 \text{ Log } (450 + 150 + 650) - 49.4 \\ &= 100 + 10 \text{ Log } (1250) - 49.4 \\ &= 100 + (10 \times 3.1) - 49.4 \\ &= 100 + 21 - 49.4 \\ &= 131 - 49.4 \\ &= 81.6 \end{aligned}$$

<u>ASDS</u> ="<u>Airport Sound Description System</u>" and utilizes the sound levels emitted by each aircraft operation to obtain a composite measure of annoyance in a manner differing significantly from CNR, NEF, Ldn, and CNEL in that the number of minutes of exposure above a criterion level are estimated, rather than cumulative sound energy. For example, an ASDS analysis might reveal that a criterion level of 85 dBA was exceeded for one minute in an average 24 hours period, while the time integrated average sound level obtained utilizing the Ldn methodology might be 53 dBA. Because the ASDS methodology arithmetically adds the number of minutes of exposure to a given sound level, the minutes of exposure are a direct function of the number of operations, i.e., if they are doubled in the example, 2 minutes of exposure are obtained—but a doubling of operations would add only 3 time integrated A-weighted decibels, e.g., 56 dBA. At this point in time, the ASDS methodology must be considered seriously deficient for the purposes of evaluating environmental impact, and may, in some instances, lead airport proprietors to pursue abatement strategies which will degrade rather than improve the environment.

<u>Noise Contours</u> = method for depicting points of equal sound level, e.g., 100 CNR, 30 NEF, 65 Ldn, 65 CNEL, etc., as a continuous line, in much the same manner as topographic contours depict points of equal elevation.

INSTRUCTIONS FOR USE OF TABLE OF COMMON LOGARITHMS



1. Count the number of digits in the number for which the common logarithm is to be determined and subtract 1.

   Example: 94,869 has 5 digits, minus 1 is 4 (four) digits

2. Write the number obtained in #1 and insert a decimal point immediately after it.

   Example: 4.

3. Enter the Log Table, column N, and find the first two digits or the original number.

   Example: 94,869 find 94 in column N

4. Read across the top of the Log chart and find the third digit, rounded to the nearest 10.

   Example: 94,869 = 94,900

5. Place the number indicated on the chart after the decimal point.

   Example: 4.9773 is the approximate logarithm of 94,869

INSTRUCTIONS FOR USE OF ANTILOG TABLE FOR DECIBEL ADDITION

Decibels may be conveniently added by using an Antilog Table, as depicted in the example below. Note that two sound levels of equal value will always result in an accumulation of 3 dB.

EXAMPLE FOR DECIBEL ADDITION

		ANTILOG COLUMNS—LEFT DIGIT OF SOUND LEVEL								ANTILOG TABLE	
SOURCE	SOUND LEVEL (dB)	9	8	7	6	5	4	3	2	RIGHT DIGIT OF SOUND LEVEL	ANTILOG
1	65				3	1	6	2		0	1000
2	73			1	9	9	5			1	1259
3	69				7	9	4	4		2	1585
4	82		1	5	8	5				3	1995
5	56					3	9	8	1	4	2512
										5	3162
										6	3981
										7	5013
										8	6311
Total	83		1	8	9	9	5	4	1	9	7944

Comments on example: For 65 dB, enter antilog table with "5" to obtain the antilog "3162," etc. Enter "3162" on work sheet, with "3" in column 6, because the left digit of 65 dB sound level is "6." This is done for all the other listed sound levels. The columns in the example add to 1899541. Round off to four digits—1900. From antilog table, 1900 is closest to 1995, the antilog of "3." The right digit of the total sound level is therefore "3."

In the example, the left-most digit of the total sound level antilog is "1" and it appears in the column headed "8." The left digit of the total sound level is therefore "8," which with Step 5 determines the total sound level as "83."

The total sound level of 65, 73, 69, 82, and 56 dB is thus 83 dB.

SIGNIFICANT DIFFERENCES, ADVANTAGES, AND DISADVANTAGES OF MEASUREMENT UNITS

The major differences between, as well as the advantages and disadvantages of, the composite measure of annoyance (CNR, NEF, Ldn, and CNEL), stem from the single event measurement units (PNdB, EpNdB, SEL, and SENEL) employed. Examination of columns 5. 6. & 7 in Table I and Figure A will reveal that each composite measure is based on the furmula of the value of the single event measurement unit plus "10 Log N" where N is the total number of operations, adjusted for thettime of day during which they occur. The expression "10 Log N" simply means 10 times the common logarithm of the adjusted operations--if operations (N) are 10, 100, and 1000, the common logarithm is 1, 2, & 3 and the expression becomes 10, 20, and 30, respectively. Note that the "Log" actually denotes the number of digits following the first digit (in this case the number of zero's). Thus, the Log of 1 is zero because zero digits follow the first. Log values for any whole number may be estimated from Table For example, 5, 50, and 5000 become 1.69, 2.69, and 3.69, respectively, and hence the expression "10 Log N" yeilds 16.9, 26.9, and 36.9.

Attention may now be focused on the major differences between CNR, NEF, Ldn, and CNEL and the advantages and disadvantages of each discussed in more detail.

CNR and NEF

CNR is the oldest composite measure of annoyance, and the first to be adopted by the F.A.A. in 1964. It is still used exclusively by the Navy, but much of the national data base has been updated by NEF. There are two subtle differences between CNR and NEF: (1) CNR uses PNL expressed as PNdB as the single event input, while NEF uses EPNL expressed as EPNdB, which contains corrections for pure tones and the duration of the overflight, and (2) CNR employs a constant of -13. From this, the analyst might erroneously assume that values of NEF might be determined by subtracting 75 from values of CNR, e.g., a point predicted to be 105 CNR will be 30 NEF for the same airport. Because of the use of EPNdB rather than PNdB, however, the values are likely to be different--the pure tone penalty for a given type of aircraft may, for example, occur at the high end of the frequency scale, and consequently measurements made in EPNdB will reflect a more rapid rate of absorption as a function of distance--the penalty may be high 1000' from the aircraft and low 5000' away.

It is for this reason that NEF is thought to be a more accurate measure of community annoyance and a superior methodology for depicting the degree and location of impact. Both NEF and CNR are included as evaluation criteria in H.U.D. Circular 1390.2 as determinants of three zones of acceptability for residential housing mortgage insurance as follows:

		CNR	NEF
(1)	Unacceptable	115	40
(2)	Discretionary - Normally Unacceptable	100-115	30-40
(3)	Acceptable	100	30

Ldn and CNEL

The Ldn methodology has been officially adopted by the U.S. Environmental Protection Agency, and differs very slightly from the CNEL methodology which has been adopted by the State of California. Two important, but not critical differences are: (1) Ldn uses SEL as the single event input, while CNEL uses SENEL, and (2) Ldn weights only night operations (10 PM - 7 AM) by a factor of 10, while CNEL applys an additional weighting of 3 for evening operations (7 PM - 10 PM). Both SEL (Ldn) and SENEL (CNEL) are derived from time integrated average sound levels measures as dBA, but the SENEL approach defines the period of time for measurement as starting 30 dBA from the peak "flyby" sound level and ending 30 dBA afterward, while the SEL approach defines it as being 10 dBA before and after the peak. This subtle difference may lead to problems for the actual measurement and monitoring of single events for SENEL, because a moderately loud peak, of, for example, 85 dBA would require measurement from the point where the aircraft first registered 55 dBA to the point where it diminished below 55 dBA. The threshold of 55 dBA is so low that it is easily and frequently exceeded by background sound levels in the community. In addition, most commercially available A-weighted sound level meters are designed to read in bands of 10 dBA, and actually measuring a range of 30 dBA involves switching scales at least twice during each measurement.

As a matter of predictive validity, there is usually very little difference between SEL and SENEL, because the slightly lower "average" sound level obtained in using the latter is largely offset by the longer duration of the measurement (to "time integrate", both SENEL and SEL add a factor of 10 times the Log of the number of seconds to the "average" sound level obtained).

Consequently, most of any observed lack of congruence between Ldn and CNEL values is likely to be due to the increased importance placed on evening operations by the CNEL methodology. Where the impact on homogenously developed residential areas is considered, this factor appears appropriate, because home occupancy is usually higher during this period.

Both Ldn and CNEL have definite advantages over CNR and NEF methodologies, because they are derived from A-weighted decibels and may therefore be readily compared with estimated, projected and actual sound levels emitted from other sources. The development of such methodologies has led to important experimentation in the field of aircraft noise impact evaluation, as exemplified by two concepts currently favored, although not officially adopted, by the Office of Noise Abatement and Control of the U.S. Environmental Protection Agency—"Fractional Impact" (FI) and "Noise Units" (NU).

FRACTIONAL IMPACT (FI)

The fractional impact of a given aircraft sound level (expressed in Ldn) is simply the difference between some reference level (again, expressed in Ldn) and the level emitted to the same point on the ground by aircraft, divided by 20. This reference level may be (1) a criterion level, or (2) a background level. Criterion levels are usually assigned to various types of land uses based on compatibility with noise. E.P.A.'s recommended level for residential development of 55 Ldn is a good example. Background levels are the measured or estimated sound levels present in a particular environment or study area. For example, homes near an urban freeway may have background sound levels of 75 Ldn or more.

Fractional impact may be determined from a criterion level as follows:

Example:

(1) Aircraft emission level = 80 Ldn

(2) Criterion level for residences = 55 Ldn

(3) Ldn exceeded by aircraft = 25 Ldn

(4) #3 ÷ 20 = 1.25 = Fractional Impact

A similar approach may be utilized for ground sources:

Example:

(1) Freeway emission level = 75 Ldn

(2) Criterion level for residences = 55 Ldn

(3) Ldn exceeded by freeway = 20 Ldn

(4) #3 ÷ 20 = 1.0 = Fractional Impact

When fractional impact is determined from a background level, the background level is merely substituted for the criterion level:

Example:

(1) Aircraft emission level = 80 Ldn

(2) Freeway background 75 Ldn

(3) Net Ldn attributable to aircraft = 5 Ldn

(4) #3 ÷ 20 = .25 = Fractional Impact

The use of a constant divider of 20 reflects consideration of recent evidence strongly supporting the contention that both human annoyance and speech interference are arithmetically direct functions of the amount by which background levels are exceeded--while background levels and emission levels from a particular factor and speech interference level are negligable, but when the background is exceeded by 20 Ldn the intruding source is consistently identified as being intolerable. This factor has also been applied in determining fractional impact from criterion levels to make criterion and background level fractional impact analyses more compatible.

The most serious shortcoming of fractional impact analyses are that they tend to confuse psychological reaction with the laws of physics, especially when the background methodology is applied. In the previous example, aircraft emissions (80 Ldn) exceeded freeway emissions (75 Ldn) by 5 Ldn. Yet, in order to be acoustically correct, the analyst would be forced to admit that if the freeway were to be removed, a benefit would be obtained. This is because the combined sound level of both sources (adding 75 Ldn to 80 Ldn) would yeild a total of 81 Ldn for a net contribution of 1 dB for the freeway--an increment that is psychologically inaudible and which would yeild a fractional impact of only .05. However, if each of three sources met the EPA criterion level of 70 Ldn for long term protection from hearing loss, their cumulative effect at a single reference point would be about 75 Ldn, well above the criterion level. Examination of the "noise units" concept will serve to delineate the advantages and constraints of fractional impact analyses.

NOISE UNITS (NU)

Noise units are simply the effected population multiplied by the applicable fractional impact. In the previous set of examples three fractional impacts were detemmined:

(1) Aircraft (80 Ldn) above criterion (55) = 1.25

(2) Freeway (75 Ldn) above criterion (55) = 1.00

(3) Aircraft (80 Ldn) above freeway background = .25

If the effected population in each case were 1000, noise units would be 1,250; 1,000; and 250, respectively. Psychologically, the aircraft contribute 250 noise units to an environment degraded by 1,000 noise units. To be acoustically accurate, however, the addition of 80 Ldn to 75 Ldn would yeild a total impact of 81 Ldn, for a new contribution of 6 dB, a fractional impact of .30, and 300 (rather than 250) noise units.

However, assuming a 10 Ldn reduction in aircraft noise (from 80 to 70 Ldn), aircraft would still contribute 1 dB to the environment (75 + 70 = 76 Ldn) for a fractional impact of .05 and 50 noise units. Psychologically, the aircraft would have a negligable effect, but acoustically the 50 noise units would exist. This becomes a very sensitive subject in the vast areas subjected to aircraft sound levels of 55 Ldn - 65 Ldn. In many such areas, indigenous residential noise is likely to exceed aircraft noise by from 1 to 6 Ldn, and hence, aircraft "contributions" would range from 3 to 1 dB for fractional impacts of from .15 to .05. The analyst should be aware that many such areas contain over 100,000 people, and that this acoustical phenomenon could account for 5,000 to 15,000 noise units.

FORECASTING AIRPORT OPERATIONS

The preceding impact evaluation methodologies and evaluation criteria are highly sensitive to the accuracy and validity of the data employed in the various models described. An existing situation may be validated by field measurements, and frequently when appropriate adjustments are made for atmospheric conditions, predicted sound levels correlate very well with measured values. When future sound levels are estimated, the potential for error is greatly increased because the accuracy and validity of input data must be questioned.

As the formulas for composite measures of community annoyance indicate, the analyst preparing an EIS must estimate the average daily operations for a mix of: (1) aircraft (2) flight tracts (3) flight profiles (4) load factors (5) stage lengths and (6) the time of day during which operations occur. The reviewer's task is somewhat simplified if he limits his investigation to (1) the adequacy of the information presented, and (2) the reasonableness of assumptions employed in the forecasting process. The test for adequacy is actually completeness, i.e., to what extent has the analyst presented the basic components of the air travel forecast? The test for reasonableness is closely related to criticality, i.e. are the assumptions and predicted variables which have the greatest potential effect on the aircraft/airport noise forecast values biased or arbitrary?

Completeness

A complete analysis of traffic and operations forecasting must include projections for air travel demand in the airport impact area, including cargo activities and consideration of the physical capacity of the airport.. Assessment of noise impact will require conversion of these two aspects into aircraft types, numbers of operations and the timing of such operations.

A. Travel demand forecasting:

Travel demand forecasting is normally carried out through a comparison of population change, per capita income levels and employment data. Projection will require analysis of trends established in prior years and inclusion of information about current economic conditions. Many regional clearinghouses will already have models through which data particular to the region have been passed in order to develop regional forecasts for growth and demands for public services.

In some instances such data may be considered in the light of the Gompertz curve, a forecasting technique best known for its application in analysis of the economic lifecycle of a new product. Under such analysis the air travel business is treated as a new product and future travel demand is projected according to the historical position of air travel in the lifecycle. (Some analysts have suggested that air travel should be considered a maturing industry, subject to a flattening of growth rates as new markets become more difficult to capture, and costs increase.)*

In In the absense of regional data systems which are capable of projecting travel demand the F.A.A. and the Air Transport Association provide data describing historical trends and projections of travel demand broken down into national, regional and airport-by-airport classifications. An additional component of demand analysis, that of origin and destination is also often included in such data, thereby providing insight into the mix of stage lengths which will characterize travel from any airport. Stage length information is a critical factor in the conversion of travel demand to aircraft types and the noise impact which they imply. Stage lengths are generally listed in terms of Long Haul-Domestic, Interurban (50-500 miles), and International, for passenger flights, though greater detail may be used when it is known. Air Cargo and General Aviation are separated, though stage length is an important component for cargo flight calculations when noise impact is being analyzed.

To distribute travel demand between the airports in a particular region, analysts will often use variations of the gravity model, whose basic equation is

$$Tij = K \cdot \frac{Pi\,Pj}{dij}$$

Where:

T = the number of transactions between places i and j
Pi = the population of i
Pj = the population of j
d (ij)= the distance between places 1 and j
k = a constant

In such analysis d may represent a time factor instead of a linear distance. Where two or more airports within a region may offer similar facilities, gravity models will provide a basis for allocation of passengers originating flights in the region.

Projections of air cargo activity will employ a slightly different set of components. Employment, annual personal income and average cargo revenue yield may be used and the results given in terms of enplaned and deplaned cargo. The following equations have been used to establish trends for cargo activity:

$$\text{Log } \frac{T}{E^1} = 1.61754 \text{ Log } Y - 1.3953 \text{ Log } R + 1.9559$$

for enplaned cargo, and

$$\text{Log } \frac{T}{E^2} = 1.6994 \text{ Log } Y - 1.6746 \text{ Log } R + 2.1484$$

for deplaned cargo, where

T = total annual volume of cargo enplanement or deplanement in millions of pounds

E = total employment in millions

Y = total annual personal income of all residents in billions of current dollars, and

R = average cargo revenue yield for all U.S. route certified carriers in current cents per revenue ton mile.**

Efforts to project general aviation usage have shown that a high correlation exists between population and aircraft ownership.*** Thus, projections for G.A. activity can be obtained by multiplying per capita ownership data by population projections. While these results may require further adjustment related to the components mentioned above, it is certainly appropriate that adjustments relating to general economic conditions in the target area be considered.

The travel demand forecasting must leave the E.I.S. reviewer with a clear picture of the mix anticipated. The percentage of registered air carrier operations, whether passenger or cargo, and the percentage of general aviation operations are critical to an understanding of the type of noise impact to be expected. Other essential output to be derived from travel demand data includes that which permits calculation of aircraft load and the time of day of operations. Both are critical in noise impact analysis.

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* "Revised Aviation Forecasts for the Bay Region." Working Paper. Port of Oakland, Oakland, California, December 31, 1974; p. 8 ff.

** *Ibid.* Appendix (Regional Airport System Plan Forecasting Equations.)

*** *Ibid.* p. 21.

B. Airport Capacity

It is likely that an E.I.S. dealing with an airport will result from a decision to alter the airport capacity in some fashion or another. The basis for classification by capacity is established by the type and length of runway, and the degree of sophistication of navigational equipment available. The more complex are the airports operations, the wider the variety of actions which may be undertaken to expand capacity. Thus, parking space for automobiles, terminal facilities and repair or maintenance facilities may be the focus of expansion efforts at major airports.

When financing of airport capacity expansion required Federal Government assistance, a much more common condition today than in the past, and the sine qua non of a project requiring an E.I.S., the F.A.A. applies certain criteria to inclusion of the project within the National Airport System Plan. Congestion levels determine the suitability for inclusion in the plans for facilities expansion. For airports with registered air carrier service capacity is reached when delays due to large aircraft departures average four minutes during normal conditions for two adjacent peak hours of the week. Capacity is reached for small aircraft airports or runways when delays reach two minutes for the peak hour of the week.

To anticipate capacity situations the National Airport System Plan has established "capacity development criteria" which rely on the ratio of operations to the airport's Practical Annual Capacity, or PANCAP. These criteria are outlined in Figure H.

When conditions call for development of a new airport facility or substantial expansion of the type of service to be offered by an existing facility, such as a change from general aviation to registered air carrier capability, the project will fall udner the category of Fundamental Airport Development. A listing of "development items" may be seen in Figure G. An indication of the impact on operations which may result from inclusion of some of the development items is given in the following quote from the 1972 NASP:

> "...Depending upon the distribution of aircraft types (aircraft mix) and frequency using a runway, a fundamental single runway—stub taxiway configuration may be capable of handling about 75,000 annual operations. The provision of a full parallel

FIGURE G

- FUNDAMENTAL AIRPORT DEVELOPMENT

Development Item	*Airports Serving General Aviation Only*	*Airports Serving Air Carrier ** and G. A.*
LAND—airfield development, building area, clear zones, approach/departure areas, approach aids	Yes	Yes
SINGLE RUNWAY—MIRL	Yes [1]	Yes [1]
CROSSWIND RUNWAY—MIRL	Yes [2]	Yes [2]
TURNAROUNDS—MITL, one each runway end	Yes	No
PARTIAL PARALLEL TAXIWAY—MITL, in lieu of one turnaround (optional)	Yes	No
FULL PARALLEL TAXIWAY—MITL	No [3]	Yes
STUB/CONNECTING TAXIWAY—MITL, as appropriate	Yes	Yes
EXTENDED RUNWAY SAFETY AREAS	No	Yes
VASI, each runway end	Yes [4]	Yes [4,5]
REILS	Yes [6]	Yes [6]
RUNWAY MARKING, as appropriate	Yes	Yes
APRON, including lighting if required	Yes	Yes
RUNWAY GROOVING, if appropriate in accordance with current criteria	Yes	Yes
ILS WITH APPROPRIATE APPROACH LIGHT SYSTEM, including land and site preparation	No	Yes [7]
ROTATING BEACON; LIGHTED WIND CONE; SEGMENTED CIRCLE [8]; OBSTRUCTION LIGHTING AND MARKING where necessary	Yes	Yes
ACCESS AND SERVICE ROADS, in accordance with FAA Order 5100.17, paragraph 122	Yes	Yes
FENCING AND MISCELLANEOUS, such as crash and fire fighting facilities, utilities, etc., in accordance with current criteria	Yes	Yes

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**Carrier must be scheduled and certificated by CAB.

[1] Include HIRL for existing and forecasted PRECISION instrument runways and for runways having an approved non-precision approach procedure.

[2] Include if required wind coverage is less than 95 percent. Do not apply 80 percent length limitation. If crosswind runway exists and is being utilized, consider it eligible for planning purposes regardless of wind coverage.

[3] Eligible for installation when runway reaches 20,000 annual operations (based on safety rather than capacity considerations). If new airport is forecast to reach this level in two years, include this taxiway as part of the fundamental configuration.

[4] Include VASI-2 for utility runways and VASI-4 for transport type runways. Recommend VASI-4 on precision instrument runways which serve substantial numbers of general aviation aircraft not equipped for precision approaches.

[5] Include VASI-6 (3 bar) for runways serving long-bodied jets. Include VASI-12 or VASI-16 (3 bar) ONLY on major international airport runways where a safety requirement substantiates the need.

[6] Include only where there is a visual deficiency and the runway is NOT a precision instrument runway.

[7] Provided the runway serves air carrier ** turbojet aircraft.

[8] Unnecessary for towered airports.

SOURCE: 1972 NASP, D.O.T.,
Federal Aviation Administration
G.P.O., Washington, D.C.; p. 26.

FIGURE H

CAPACITY DEVELOPMENT CRITERIA

Capacity Development Item	*Recommend for Inclusion at Forecast*	*Remarks*
Runway (Additional)	60% × PANCAP	1. Parallel preferred 2. Same length and strength as primary if serving same aircraft
Short Runway	75,000 total operations including 30,000 or more by transport type aircraft	1. Small aircraft only 2. Not necessarily parallel
Extension of a Parallel Runway	60% × PANCAP	
Additional Taxiways	60% × PANCAP	
Additional Exit Taxiways	40% × PANCAP	
Holding Apron/By-Pass Taxiway	75,000 total operations 20,000 itinerant operations or 30 peak hour operations	1. Need dependent upon aircraft mix 2. Consider effect on NAVAIDS 3. Limit holding apron to 4 aircraft positions
Terminal Aprons, Aircraft Loading Aprons, Parking Aprons	60% × PANCAP	Consider aircraft movements on edge taxiways
Supplemental/Replacement Airports	Not Later Than 60% × PANCAP	Timing depends upon forecast, type of airport, location (Metropolitan Area), etc.

SOURCE: <u>1972 NASP</u>, D.O.T., Federal Aviation Administration, G.P.O., Washington, D.C.; p. 27.

> taxiway system can increase annual capacity to over 150,000 operations. The addition of a parallel runway and taxiway system to this configuration can double the annual capacity to well over 300,000 operations depending upon the appropriate runway spacing provided to accommodate uninhibited VFR and IRF simultaneous operations."*

C. Types of Aircraft

The translation of travel demand data into aircraft types is a difficult but vital part of noise impact analysis. Section 1 has described the properties of aircraft noise and the variations by type. In addition the stage length of any given aircraft on any given operation has great importance in noise impact determination. Table IIA, Table III and the related noise contours described in Figures I - Q provide a summary of aircraft types, distance capability and basic noise "foot-print." Table IIIA also reflects the seating capacity of the major passenger aircraft types. Analysis of this data makes clear the importance of aircraft mix in any calculation of airport noise impact.

D. Other Essential Components

Among those components considered essential for any noise impact analysis is a group related to scheduling and direction. The direction of prevailing winds, and such scheduling factors as the destination of flights, the time of day and the airport's geographic location have great importance. The prevailing winds generally dictate take-off and landing direction, or in the case of planning for a new facility, the alignment of runways. In situations of substantial existing noise impact, for example, the ability to redirect flight paths so as to avoid concentrations of population may be a tremendous asset in the struggle to reduce impact. Because night time activities have the disadvantage of a more sensitive population in the impact area, scheduling offers the possibilities of shifting noise impact to more tolerable times of day. In some cases this may be difficult, however, if the airport's location and the predominant destination of flights tie the facility to time zones which influence the schedule (e.g., it is preferable to fly to Europe from New York at night; there is no loss of a working day as the flights arrive early the next morning.) These factors may severely circumscribe the use of scheduling changes within a noise abatement program.

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* 1972 National Airport System Plan. Vol. AAS, Narrative and National Summaries, U.S. Dept. of Transportation, Federal Aviation Administration. G.P.O., Washington, D.C.; p. 24.

CERTIFIED, SCHEDULED
AIR CARRIER AIRCRAFT GROUPS

TABLE III-A

Aircraft Groups**	Length of Haul	Code
A		
B-747		
DC-8		
B-707	Code 1--Over 1,500 Miles	A1
VC-10	Code 2--500-1,500 Miles	A2
C-5A	Code 3--0-500 Miles	A3
Future		
SST		
B		
B-727		
B-737	Code 1--Over 1,500 Miles	B1
DC-10	Code 2--500-1,500 Miles	B2
L-1011	Code 3--0-500 Miles	B3
BAC-1-11		
DC-9		
C		
L-188		
F-27		
F-227	Code 1--N/A*	--
YS-11	Code 2--500-1,500 Miles	C2
CV-580	Code 3--0-500 Miles	C3
M-404		
V-724		

* These aircraft do not generally have a haul length over 1,500 miles.

** Aircraft are grouped in accordance with general runway requirements and not by physical size or passenger carrying capacities.

SOURCE: 1972 National Airport System Plan, Vol. AAS, Narrative and National Summaries; U.S. Department of Transportation, Federal Aviation Administration. U.S. Government Printing Office, Washington, D.C.; p. 20.

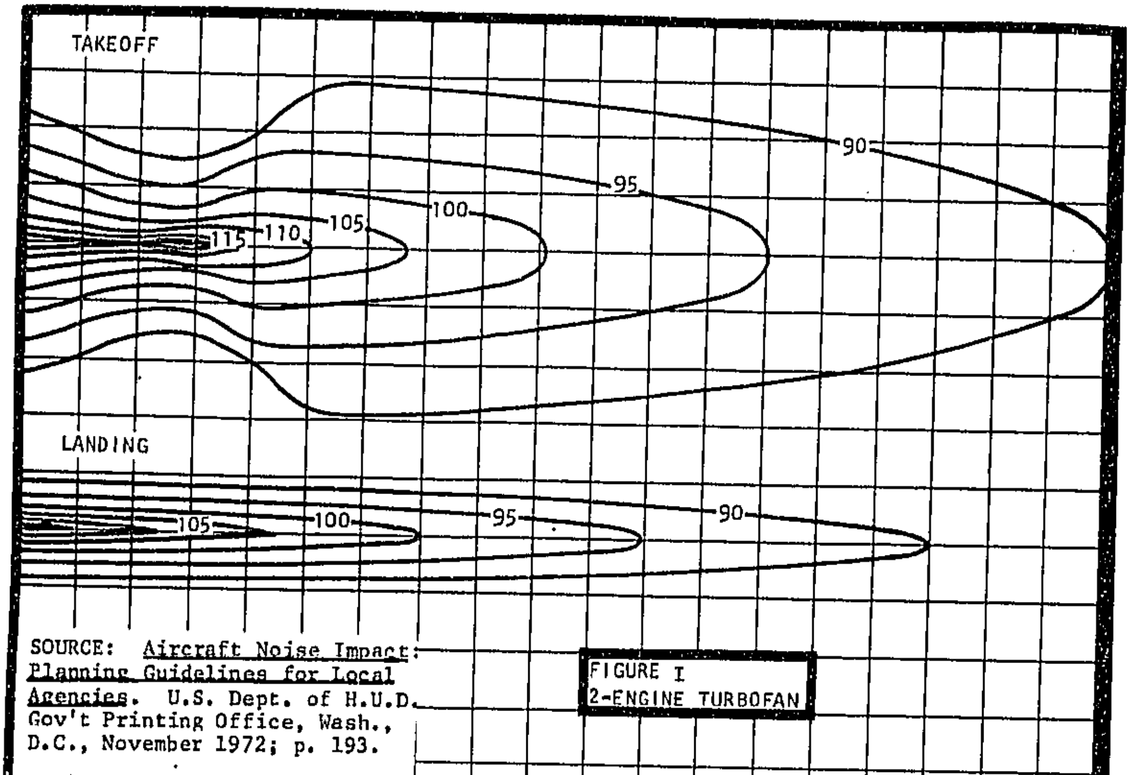
TABLE III-B

USE OF AIRCRAFT EPNL CONTOURS

AIRCRAFT TYPE	EXAMPLES	EPNL CONTOUR FIGURE
2-engine transport	Boeing 737 Douglas DC-9 BAC 111	I
Business Jet	Lockheed Jetstar Sabreliner, Lear Jet, Jet Commander, Gulfstream II	J
3-engine turbofan transport	Boeing 727-100 727-200	K
3-engine high bypass ratio turbofan	Douglas DC-10 Lockheed L-1011	L
4-engine turbofan transport	Boeing 707 Douglas DC-8	M
4-engine high bypass ratio turbofan	Boeing 747	N
4-engine piston and turboprop transport	Douglas DC-6, -7 Series Lockheed Constellation Lockheed Electra	O
2-engine piston and turboprop, over 12,500 lbs max. gross wt.	Convair 340,440 Series Douglas DC-3 Fairchild F-27 Series Grumman Gulfstream I	P
2-engine propeller, under 12,500 lbs. max. gross wt.	Piper Twin Comanche, Aztec; Cessna 310, Beech Baron, etc.	Q

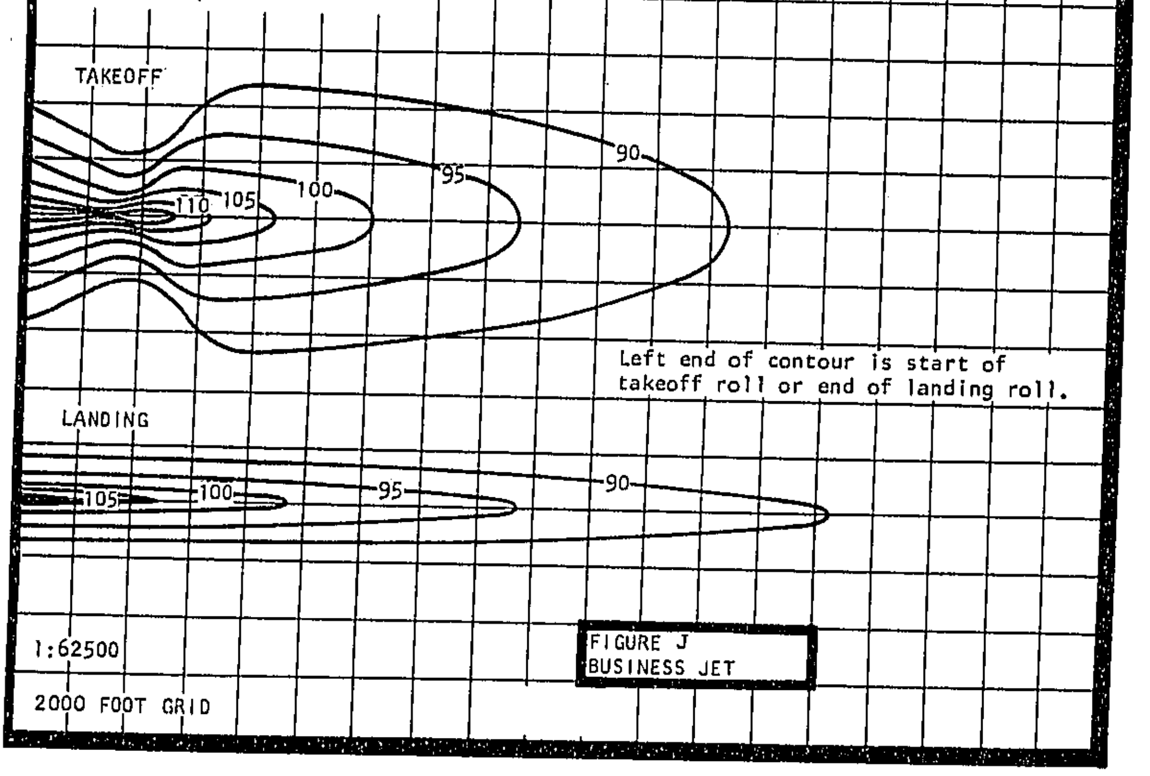
SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of Housing & Urban Development. Government Printing Office, Washington, D.C., November 1972; p. 192.

AIRCRAFT EPNL CONTOURS



SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 193.

FIGURE I
2-ENGINE TURBOFAN



Left end of contour is start of takeoff roll or end of landing roll.

FIGURE J
BUSINESS JET

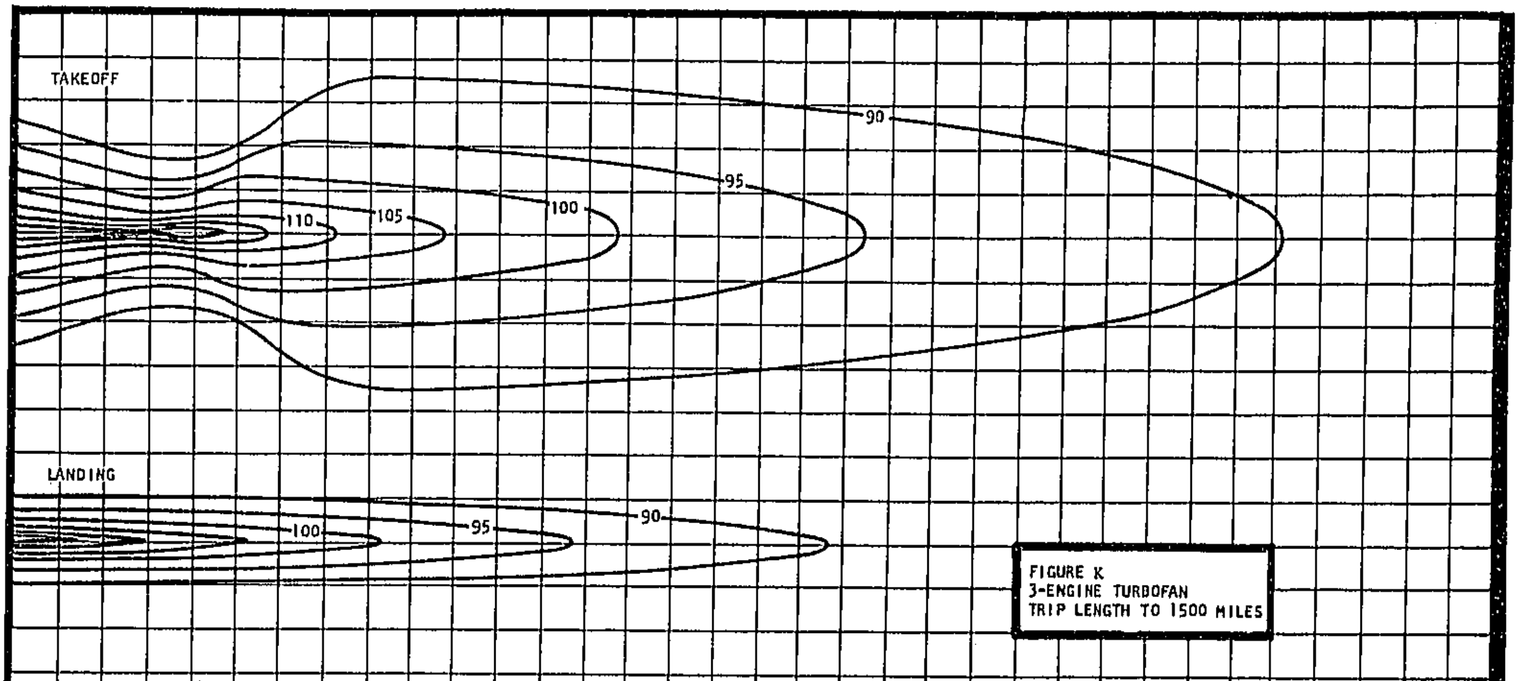
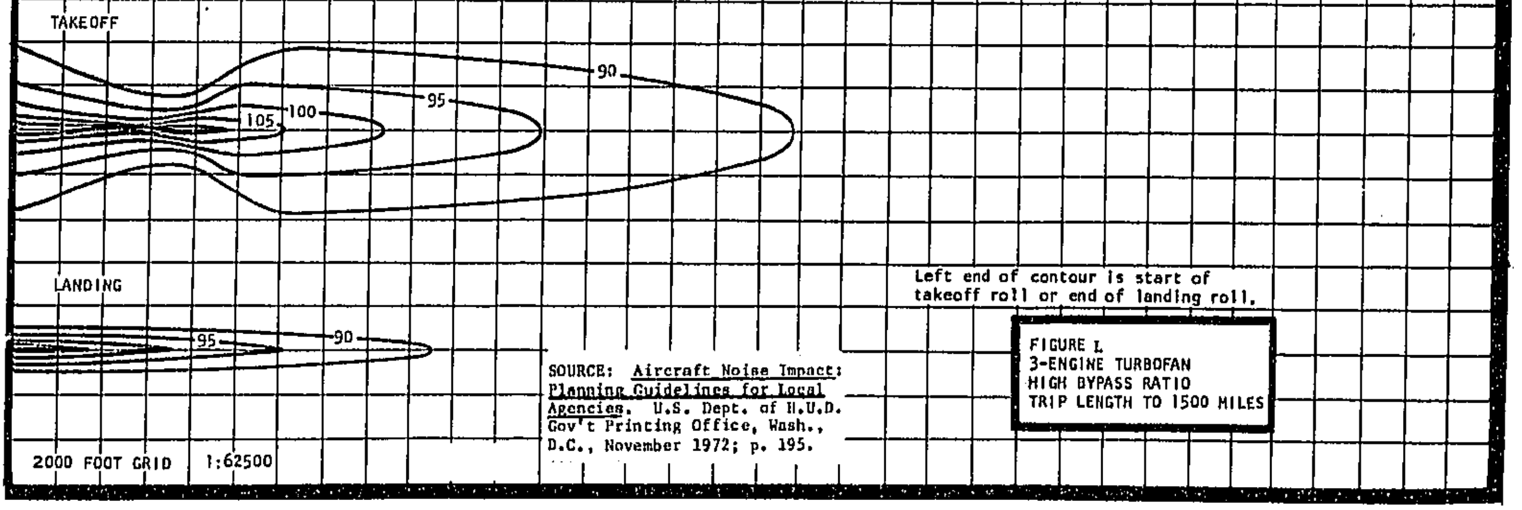


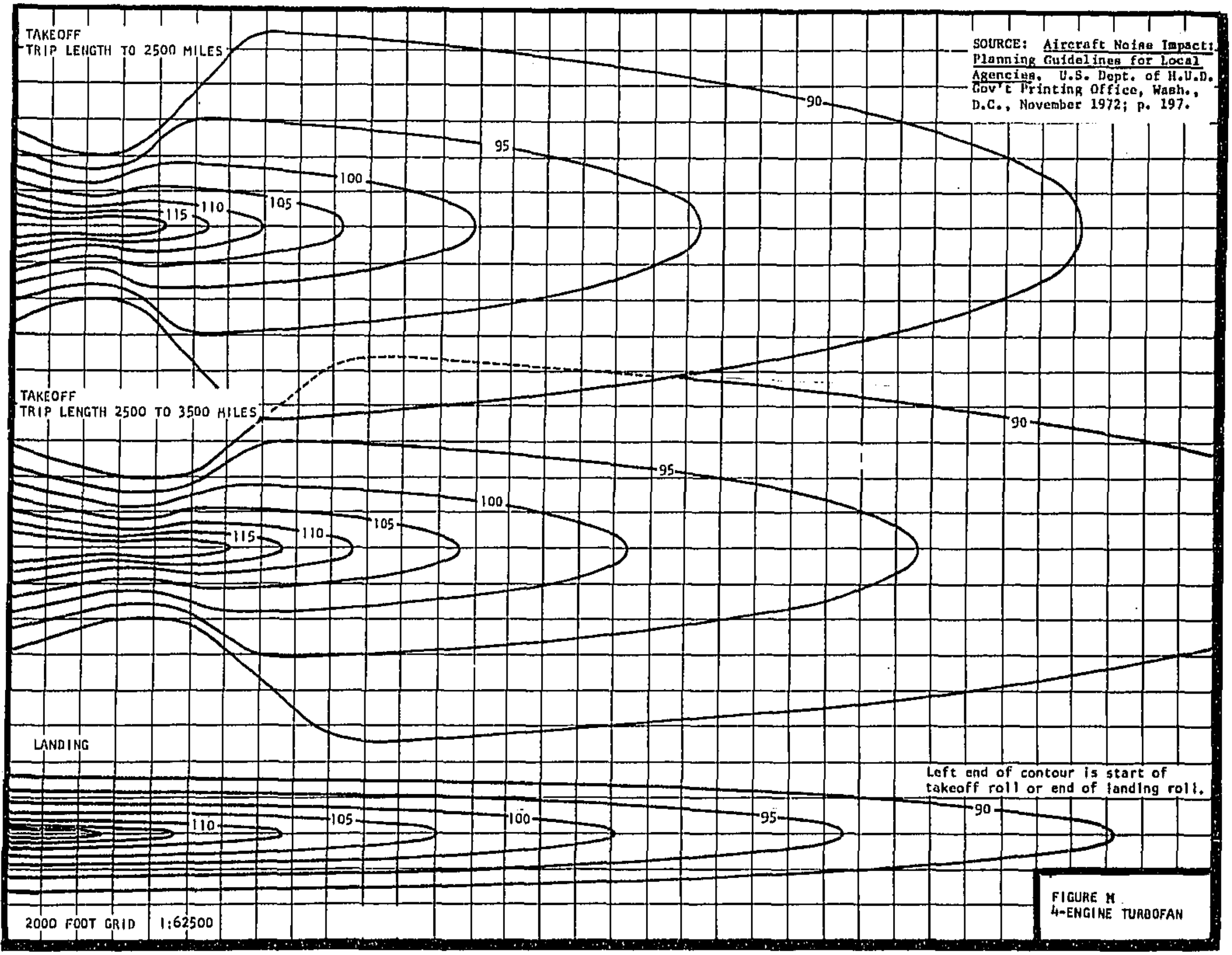
FIGURE K
3-ENGINE TURBOFAN
TRIP LENGTH TO 1500 MILES



Left end of contour is start of takeoff roll or end of landing roll.

FIGURE L
3-ENGINE TURBOFAN
HIGH BYPASS RATIO
TRIP LENGTH TO 1500 MILES

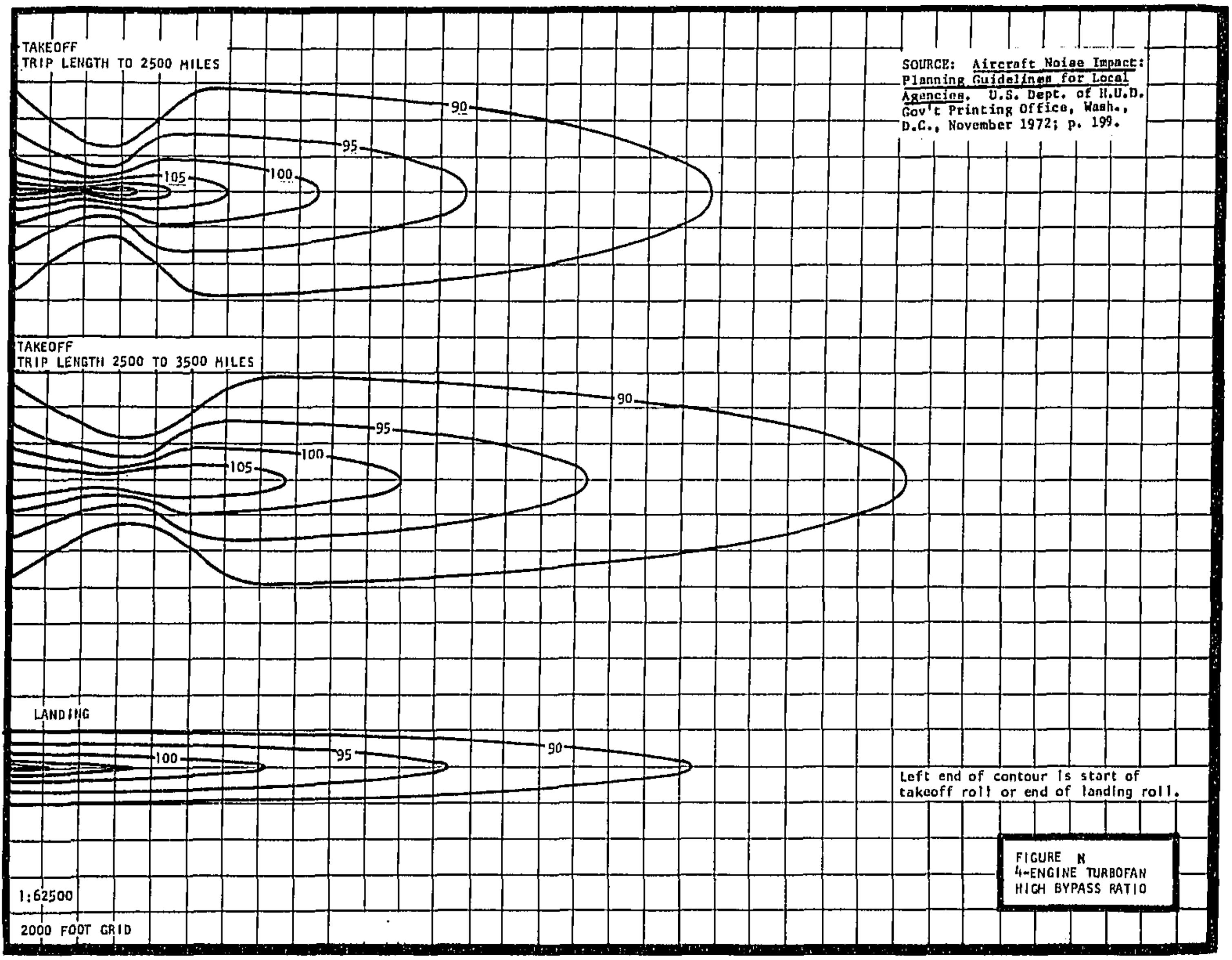
SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 195.



SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 197.

Left end of contour is start of takeoff roll or end of landing roll.

FIGURE M
4-ENGINE TURBOFAN



SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 199.

Left end of contour is start of takeoff roll or end of landing roll.

FIGURE N
4-ENGINE TURBOFAN
HIGH BYPASS RATIO

AIRCRAFT EPNL CONTOURS

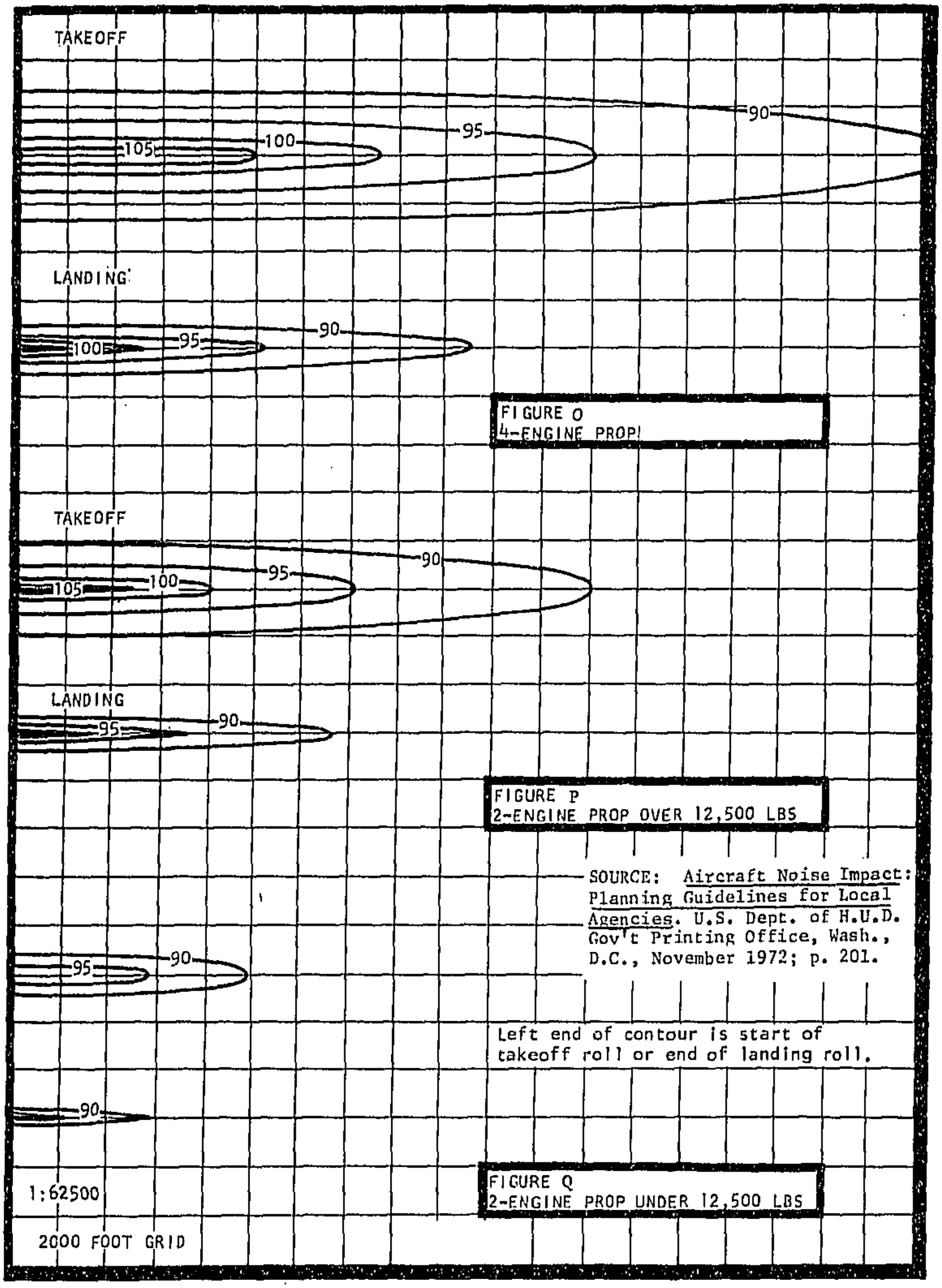


FIGURE O
4-ENGINE PROP

FIGURE P
2-ENGINE PROP OVER 12,500 LBS

SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 201.

Left end of contour is start of takeoff roll or end of landing roll.

FIGURE Q
2-ENGINE PROP UNDER 12,500 LBS

To be complete the E.I.S. analysis must reflect the appropriate mixture of the above components. To be reasonable the mixture cannot anticipate technological change at rates in advance of those accepted by the Federal Government or the other components of the aviation industry. Nor can it anticipate demand for travel in excess of that allocated by study of regional trends. Finally, the analysis must paint a reasonable picture of the expected noise impact, not over dramatic, in an effort to bring about protective actions which might require excessive public investment, nor underplayed in an effort to submerge the plaguing noise problem.

Reasonableness

To assure reasonableness, therefore, the E.I.S. analysis will have to comprehend the importance of the components described above. Certian of these components have a much greater bearing on noise impact determination than might be expected. Thus the criticality of assumptions made about these components, and an example of their mix are the foci of the following paragraphs.

Several factors may combine which will provide the analyst with a proclivity for either overestimating or underestimating the extent of the noise problem for a given airport. In general, airports in undeveloped areas with little or no existing incompatible land use will benefit from an exaggeration of a future noise environment, while those experiencing extensive incompatible land useage (especially where litigation is of concern) will benefit from conservative estimates.

The rationale of exaggeration in the former case amounts to an attempt to preempt a sufficient amount of acoustical space to give the airport proprietor the maximum amount of flexibility in future planning and programming for rapid growth. Federal and state policies tend to discourage incompatible development in zones of intensive aircraft noise, and hence, in preventive situations it is advantageous to depict a substantial future impact. The rationale for conservatism in impact forecasting in the latter case amounts to a pragmatic approach to avoiding or ameliorating litigation and obtaining requisite Federal and State assistance.

In most cases, however, it is advantageous for the proprietor to demonstrate a high volume of airline passengers and terminal users with a low volume of operations--especially where this may be accomplished by assuming high load factors on wide bodied or new FAR 36 aircraft. Where existing or programmed runway capacities do not permit the heavier and substantially quieter aircraft, the existing Boeing 737 and developing 727-300 would be favored in forecasting fleet mix. The following example will demonstrate how certain variables and assumptions may be advantageously manipulated to suit the purposes of the analyst.

Example:

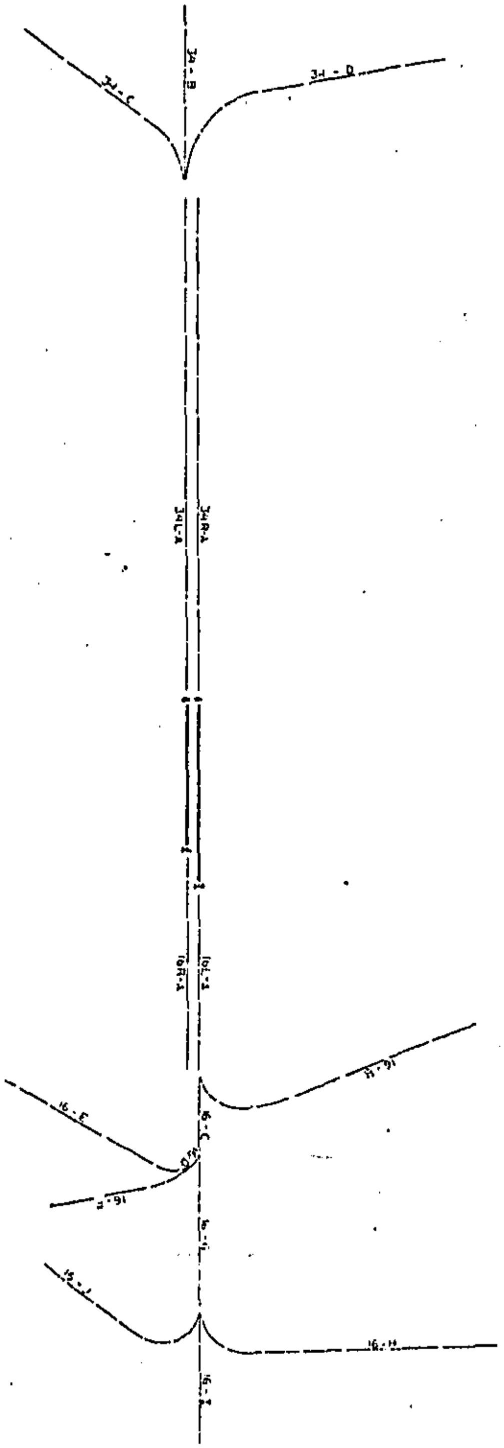
Step 1 Macro and micro economic variables (usually population, income, and employment) are analyzed for the region the airport serves to determine air travel demand. The output is the number of gross regional passenger enplanements, and tons of air cargo.

Step 2 Passenger enplanements are assigned to the airport in question based on the accessibility and service level of other airports serving the same market. The output is usually the net passenger demand and tons of air cargo for the airport in question. This projection is frequently used in expanding terminal and parking facilities as well as improvements in ground access to accommodate increasing congestion.

Step 3 All of the passengers and cargo forecasted in Step 2 must be assigned to aircraft in order to determine the number of aircraft operations for the forecast year. Generally an average capacity and load factor are assumed or estimated. For example, if the airport in question were assigned 8,869,500 passengers, and the average aircraft were assumed to have a 150 seat capacity, with an average load factor of 66.7%, one would expect 88,695 departures. (Departing aircraft = 8,869,500 ÷ 150 x .667). Since there must be an arrival for every departure, the total operations would be twice this amount, or 177,390 annual operations. The average annual daily operations (per 24 hour period) would be 177,390 ÷ 365 or 486.

Step 4 An estimate must also be made of the mix of aircraft comprising the fleet serving the air facility, the time of day during which they would operate, and the stage length of their operation upon departure. A typical method of depicting the output of such an analysis is as follows:

__Step 5__ Meterological data and historical approach and departure patterns may then be examined to determined flight track utilization percentages for the airport, for takeoffs and landings. A typical method for depicting such flight tracks and percentages appears below:



FLIGHT TRACK	TAKEOFF	LANDING
16R-A	6.56	3.67
16L-A	59.04	33.03
16-B	19.20	0.0
16-C	46.40	36.70
16-D	9.00	0.0
16-E	7.70	0.0
16-F	1.30	0.0
16-G	37.40	36.70
16-H	0.0	10.80
16-I	37.40	21.60
16-J	0.0	4.30
34R-A	5.16	12.66
34L-A	29.24	50.64
34-B	0.0	7.20
34-C	28.90	56.10
34-D	5.50	0.0

TABLE VI

SOURCE: Aircraft Noise Analyses for the Existing Air Carrier System, Bolt Beranek and Newman, Inc.; (Submitted to Aviation Advisory Commission, Wash., D.C.), September 1972.

			TAKE-OFFS STAGE LENGTHS IN NAUTICAL MILES						
AIRCRAFT TYPE		LANDINGS	0-500	500-1000	1000-1500	1500-2500	2500-3500	3500-4500	4500 And Over
4 ENG TFAN	DAY	39.840	11.950	9.960	7.970	5.980	0.0	1.990	1.990
	NIGHT	9.960	3.980	2.990	1.990	0.0	0.0	1.000	0.0
3 ENG TFAN	DAY	31.750	15.880	6.350	3.170	6.350	0.0	0.0	0.0
	NIGHT	5.600	3.360	1.120	1.120	0.0	0.0	0.0	0.0
3 ENG STRFAN	DAY	56.030	28.010	14.010	11.210	2.800	0.0	0.0	0.0
	NIGHT	6.220	2.490	1.870	1.240	0.620	0.0	0.0	0.0
2 ENG TFAN	DAY	9.960	7.970	1.990	0.0	0.0	0.0	0.0	0.0
	NIGHT	2.490	2.240	0.250	0.0	0.0	0.0	0.0	0.0
4 ENG HBPR	DAY	31.750	0.0	3.180	3.180	12.700	9.520	0.0	3.170
	NIGHT	5.600	0.0	1.120	0.560	2.800	1.120	0.0	0.0
3 ENG HBPR	DAY	42.330	4.230	8.470	10.580	12.700	6.350	0.0	0.0
	NIGHT	7.470	1.490	1.490	2.250	1.490	0.750	0.0	0.0

TABLE VII

SOURCE: <u>Aircraft Noise Analyses for the Existing Air Carrier System</u>, Bolt Beranek and Newman, Inc.; (Submitted to Aviation Advisory Commission, Wash., D.C.), September 1972.

Note that at this point the effects of different aircraft have been "averaged." Thus, where 50% of all landings traverse flight track 34L-A, this amounts to about 122 daily landing operations and it is assumed that during the year the mix of aircraft serving the airport will be approximately the same as that utilizing track 34L-A. Note also that the main tracks designated as "A" (16R-A, 16L-A, 34R-A and 34L-A) total 100% for takeoffs and landings--the lower alphabetical designations may exceed 100% because they serve both runways.

Step 6 The distribution of aircraft operations determined in Step 4 may then be assigned to flight tracks and time integrated average sound levels estimated for any point on the ground. Points of equal loudness comprise the contours which are employed as a graphic summary of aircraft noise impact.

To demonstrate the criticality of specific variables and assumptions, we shall establish a reference point directly under the flight track 16L-A, 20,000 feet from brake release for specific types of aircraft and examine such variables as (1) takeoff weight, (2) flight track, (3) load factor, (4) aircraft mix, (5) time of day, and (6) flight profile.

1. Takeoff Weight

The following depicts altitudes as a function of distance from brake release for three gross takeoff weights for the Boeing 737. Simple interpolation and the assumption of a full power climb without thrust cut-back yeild the indicated altitides at the 20,000 foot reference point as a function of takeoff weight:

Weight (lbs.)	Altitide $2 \times 10^{4'}$ from Brake Release
70,000	4,000
90,000	2,462
110,000	1,667

The indicated altitudes would yeild SEL and EPNL values at the reference point as follows:

Weight (lbs.)	SEL	EPNL
70,000	94.5	97.5
90,000	98.7	102.0
110,000	102.3	105.7

If all of the aircraft using 16L-A were 737 aircraft, 59% of all takeoffs, or 143 operations (.59 x 243) would occur.

2. Time of Day

For the purposes of this sensitivity analysis, the ratio of night to day operations may be assumed to be (1) zero (2) 10% or (3) 20%, yeilding effective operations for Ldn and NEF as follows:

% Night Operations	Ldn Ops.	NEF Ops.
0	143	143
10	272	367
20	404	597

From this the following Ldn and NEF values may be computed for the reference point.

% Night OPS	Ldn as a Function of Takeoff Weight & % Night Operations		
Weight	0	10	20
70 K	66.7	69.4	71.1
90 K	70.9	73.6	75.3
110 K	74.5	77.2	78.9

% Night OPS	NEF as a Function of Takeoff Weight & % Night Operations		
Weight	0	10	20
70 K	31.1	35.1	37.3
90 K	35.6	39.6	41.8
110 K	39.3	43.3	45.5

The reviewer should note that while both Ldn and NEF values are very sensitive to changes in the % of night operations, both are extremely sensitive to takeoff weight and the combined effect of both variables can introduce a deviation of 12-14 dB. In the most extreme case an area predicted to be "discretionary" for residential development (31.1 NEF) could actually become uninhabitable (45.5 NEF) with changes in takeoff weight and night operations. This relationship is pointedly clarified where the reviewer notes that one 110,000 pound 737 operated at night will equal 63 day operations of the 70,000 pound 737 utilizing the Ldn methodology, and 138 operations using the NEF methodology.

3. Flight Track

Deviations in flight tracks may be obtained by prescribing turns on takeoff or approach. Reductions in sound levels received on the ground are a function of the increased distance between the reference point and the aircraft. This distance is often referred to as the "slant distance" because any operation other than a direct overflight will generate a geometric frame of reference such that the actual distance to the aircraft is described by the hypotenuse of a right triangle where the height is the altitude of the aircraft to the nearest point on the ground, and the base is the distance from that point to the reference point.

The lower the aircraft, the more rapidly the slant distance increases as a function of flight track deviation. For example, the direct overflight of the 70,000 pound 737 would expose the 20,000 foot reference point to 94.5 SEL from an altitude of 4,000 feet. A deviation in the flight track or 3,000' would increase the distance between the aircraft and the reference point from 4,000' to about 5,000' for a 25% increase in slant distance. The 110,000 pound aircraft, on the other hand, would have an initial distance of 1,600' from the reference point but a deviation in flight track of 3,000' would increase the slant distance to about 3,400', increasing it by 1,800' or about 212%. The 3,000' deviation would therefore decrease the sound level in the former case from 94.5 to 91.2 SEL (-3.3 dB) and in the latter case from 102.3 to 95.8 SEL (-6.5 dB).

Of course, there are limitations to such procedures, because if the requisite turn on approach is too sharp, additional power will be necessary to maintain the desired glide slope. Similarly, turns on takeoff may result in lower altidudes as a function of distance from brake release. Although it is not within the scope of this document to provide the reviewer with the technical capability to determine the actual effect of flight track deviations, one should be congizant of the sensitivity of this variable and require the analyst to provide sufficient information for the reviewer to ascertain whether the approach taken is reasonable and unbiased.

4. Flight Profile

The trajectory of an aircraft may be voluntarily changed by its pilot, within the constraints defined by its weight, power, aerodynamic characteristics and meterological conditions. Two voluntary alterations in flight profile have received considerable attention in recent years; (1) two segment approaches, and (2) thrust cut-back on takeoff.

A two segment approach is basically an attempt to keep the aircraft as high as possible as long as possible. Many standard approach glide slopes are between 2.5° and 3°. Where an initial "steep" glide slope of 6° is utilized, it may intercept the final 3° slope at a variety of distances from the runway threshold and altitudes. The closer to the runway threshold is the point of interception, the lower the altitude of transition, and the greater the benefit in areas with the highest noise imapct. In addition to maintaining a greater distance between the aircraft and the ground, less power is required during the 6° segment, further reducing emissions. For example, one type of two segment approach prescribes a 6° initial glide slope, intercepting a 3° glide slope at an altitude of 1,000', three miles from runway threshold. Such a procedure would result in reductions of from 0-10 EPNdB, with the greatest reductions occurring at distances of 5-10 miles from the airport. Another type of two segment approach prescribes an initial glide slope of 6°, intercepting a 3° glide slope at an altitude of 250-400', less than one mile from the runway threshold. Such a procedure could result in reductions from 5-15 EPNdB, with substantial benefits accruing in high noise zones.

Although safety and pilot workload considerations have delayed the adoption and promulgation of uniform two segment approaches, the glide slope is a fairly sensitive variable, and the reviewer should check the analyst's assumptions for reasonableness. In our example, the analyst could assume a 6° glide slope for the forecast year, or utilize an existing 3° glide slope, for flight track 16L-A. The 737 aircraft would pass over the reference point about 10,000' from runway threshold, (assuming a 10,000' runway length) at an altitude of 1,051' for the 6° glide slope condition, and 524' for the 3° condition, exposing the observer to 94 SEL and 99 SEL, respectively. (Values for

EPNL are about 98 and 105.8, respectively.) Noting that 16L-A is used for approach 33% of the time, it may be estimated that about 80 operations occur per 24 hour period. Again, assuming 1, 10 and 20% night operations the following values may be calculated for Ldn:

% Night OPS Approach Profile	0	10	20
6°	63.6	66.4	68.1
3°	68.6	71.4	73.1

and NEF:

% Night OPS Approach Profile	0	10	20
6°	29.0	33.1	35.2
3°	36.8	40.9	43.0

The reviewer should note that the difference between the 3° mode and 6° mode is +5 Ldn regardless of the percentage of night operations. The combined effect of the two could result in a difference of +9.5 Ldn.

NEF is even more sensitive to the 6° approach mode, with a difference of +7.8 NEF for all night operation percentages, and +13 NEF of the combined effect.

The sound levels obtained from both takeoff and approach analyses may be "added" (see example, page 19), to obtain the total noise impact for all operations at the reference point under 16L-A, such that the sensitivity of the variables of approach glide slope, percentage of night operations and takeoff weight may be examined in our example. The range of possible deviation is best demonstrated by the set of assumptions which would minimize forecasted impact with those which would exaggerate it, i.e., lowest gross takeoff weight, no night operations, and 6° glide slope with highest gross takeoff weight, 20% night operations and 3° glide slope. The results may be depicted as variations in predicted Ldn and NEF values for boeing 737 aircraft for a reference point directly under a flight track 20,000 feet from brake release and 10,000 feet from runway threshold.

Criteria	Worst Condition (3° approach, 110K takeoff wt. and 20% night operations)	Best Condition (6° approach, 70 K takeoff wt. and no night ops.)
NEF	47.5	33.1
Ldn	80.0	68.5

The effect of the thrust cut-back option is extremely difficult to evaluate without detailed consideration of land use patterns in areas impacted by the flight track in question. A typical thrust cut-back procedure involves a full power climb on rotation (usually with a steep initial deck angle) followed by a rapid retraction of slots, flaps and landing gear which will place the aircraft in a "clean" flying configuration with a minimum amount of drag at a specified altitude (1500' is usually reasonable). The attitute of the aircraft and power settings are then adjusted such that a minimum rate of climb (about 500' per minute) is obtained. The actual power setting necessary to achieve this will vary by aircraft type and weight.

The procedure is most effective for two and three engine aircraft equipped with low bypass ratio engines (737, 727, and DC-9) where reductions of from 5 to 10 dB (EPNL and SEL) are possible at the point of thrust cut back, depending on the weight of the aircraft. However, the use of a minimum rate of climb will place the aircraft at significantly lower altitudes at greater distances from the cut-back point, resulting in an actual increase in noise levels in outlying areas above that which would result if a full power climb out procedure were utilized. The effectiveness of the procedure therefore becomes a function of where noise sensitive land uses are located.

5. Aircraft Mix

Of course, the assumption that all aircraft utilizing 16L-A are boeing 737's is not tenable and has been utilized as a matter of convenient simplification. It is a fortunate paradox that the largest aircraft in the commercial fleet today (DC-10, L 1011, and B 747) are substantially quieter than smaller aircraft with lower capacities. Reductions of from 5 to 15 EPNL and 7-12 SEL may be observed for the modern aircraft equipped with high by-pass ratio engines meeting FAR Part 36 noise standards, depending on the distance from, mode of operation and types of low bypass ratio powered aircraft used for comparison.

If the reviewer considers the data presented for the approach configuration under "landings" in Table , he will note that about 87 HBPR operations out of 243 total operations are projected for the airport as a whole. Since 33% of these will approach on flight track 16L-A, about 29 out of 81 overflights will be FAR part 36 certified aircraft, of which about 16 will have 3 engines (DC-10 and L1011) and 13 will have 4 engines (B-747). By assuming a 3° approach glide slope, the relative contribution from each aircraft type may be quickly calculated of the ground reference point 10,000 feet from runway threshold directly under the flight track. Utilizing the Ldn methodology, we may obtain the following day/night average sound levels by aircraft type:

DISTANCE = 524'

		OPS	$N_D + 10N_N$	10 Log N	SEL	Ldn
4 eng T	D	13.15	45.85	16.6	106.9	74.1
	N	3.27				
3 eng T	D	10.48	28.98	14.6	101.0	66.2
	N	1.85				
3 eng ST	D	18.48	38.98	15.9	101.0	67.5
	N	2.05				
2 eng T	D	3.27	11.47	10.6	99.0	60.2
	N	.82				
4 HB	D	10.48	28.98	14.6	180.4	65.6
	N	1.85				
3 HB	D	13.96	38.66	15.8	95.9	62.3
	N	2.47				
						76.3

Note the dominance of the 4 engine turbofan powered aircraft (707, 720-B, DC-8), even though only about 16 operations occur-- 64 overflights by other types contribute only 2.2 Ldn to the total. A similar analysis may be conducted for the takeoff condition, if the simplifying assumption may be made that all aircraft will reach an altitude of 2,500 feet by the time they pass over the reference point. Although the reviewer should be cognizant of the fact that differences in takeoff weight and aircraft performance will introduce variations similar to those discussed in the pertinent sections above, the dominance of the 4 engine turbofan aircraft is valid because it is precisely this group of aircraft which would be least likely to achieve an altitude of 2,500' at the reference point.

DISTANCE = 524'

		OPS	N_D+10N_N	10 Log N	SEL	Ldn
4 eng T	D	23.51				
	N	5.86	82.11	19.1	102.6	72.3
3 eng T	D	18.73	51.73	17.1	100.7	68.4
	N	3.30				
3 eng ST	D	33.06	69.76	18.4	100.7	69.7
	N	3.67				
2 eng T	D	5.89	20.59	13.1	98.7	62.4
	N	1.47				
4 HB	D	18.73	51.73	17.1	99.6	67.3
	N	3.30				
3 HB	D	24.98	69.1	18.4	93.7	62.7
	N	4.41				
						75.9

When considering the takeoff mode in the example, it is evident that although the 4 engine turbofan aircraft comprise only 29 of 143 operations tyep account for 72.3 Ldn at the reference point--the other types contribute an additional 3.6 Ldn for a total of 75.9 Ldn.

FORECASTING LAND DEVELOPMENT

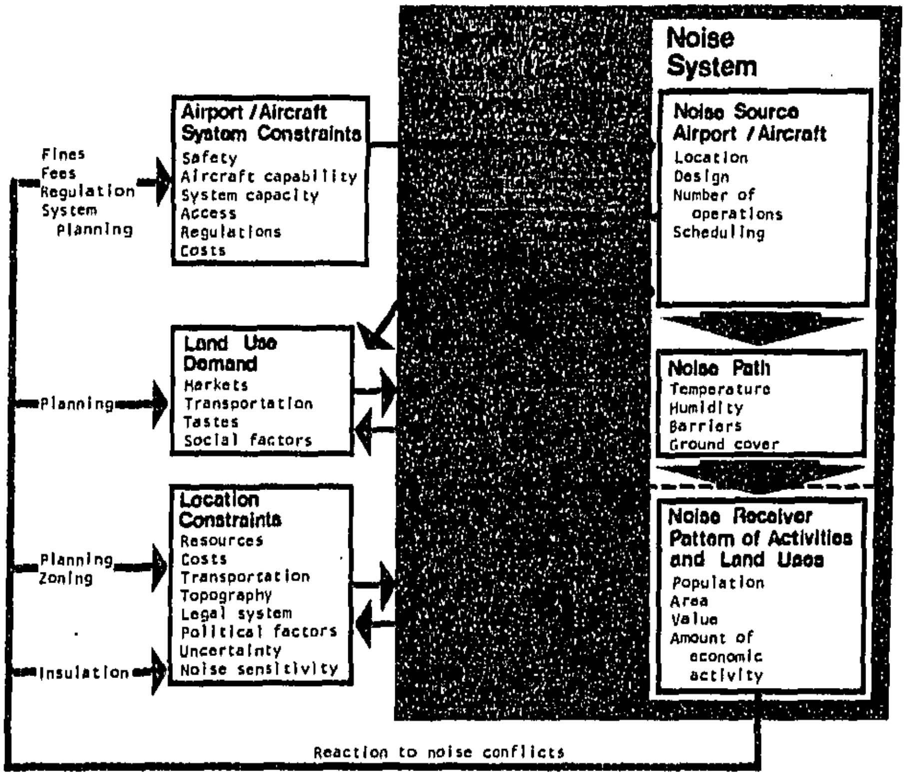
The traditional isolation of airport facilities development from neighboring land development programs and policies has been abruptly ended in recent years by the increased objection of the airports' neighbors to the noise impact of aircraft. Thus, any future airport development must be considered in the context of local development in addition to the more familiar requirements of regional and national travel or freight demands and scheduling. The most comprehensive indication that such a coordination has taken place would appear in the General or Master Plans for the localities surrounding the airport. In the absence of such documents E.I.S. reviewers should require evidence of coordination drawn from a variety of other public documents or actions, such as official zoning maps, public facilities plans and regional plans. Greater detail on these instruments of land development and programming policy is given below. An E.I.S. should be considered unacceptable, however, if no concrete reflection of such planning and programming coordination is included. (See Figure R.)

A. Population—A Critical Variable

At times, the level of sophistication obtained in forecasting the noise environment may lead the analyst and reviewer to an erroneous interpretation of future impact because of inadequate or incomplete consideration of the future use of land in aircraft noise impact zones. Determining the "absorption rate" for various land uses in a specific study area within a larger and more complex economic trade area is, at best, complicated conjecture. Yet, the location of noise sensitive land uses and populations, as well as hourly variations in the occupancy of structures are critical variables which must be examined with care.

For example, when determining the number of noise units in a particular study area developed for residential use, the "population" is multiplied by the fractional impact attributable to aircraft, even though the actual population of the area is likely to fluctuate considerably between daytime and nightime periods. If a given study area contained 1,000 dwelling units, and an average of 3.6 persons per unit, a gross population of 3,600 would result. However, with children attending school, workers migrating to jobs and other household members engaging in recreational and shopping trips during the day (7 AM to 10 PM), daytime average hourly occupancy could drop to

FIGURE R
THE AIRPORT/AIRCRAFT/LAND USE SYSTEM



SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of Housing & Urban Development. Government Printing Office, Washington, D.C., November 1972; p. 8.

1.6 persons per dwelling unit, or 1,600 gross population.

If the study area were exposed to 90 SEL from each of 300 aircraft operations, 270 of which occurred during the day, and 30 at night, and Ldn exposure rating of 68.2 would be obtained:

$$\begin{aligned} \mathrm{Ldn} &= \mathrm{SEL} + 10 \text{ Log } (N_D + 10N_N) - 49.4 \\ &= 90 + 10 \text{ Log } (270 + 300) - 49.4 \\ &= 90 + 27.6 - 49.4 \\ &= 68.2 \end{aligned}$$

However, the daytime equivalent, Ld, would be 67.0:

$$\begin{aligned} \mathrm{Ld} &= \mathrm{SEL} + 10 \text{ Log } N - 10 \text{ Log } T \\ &= 90 + 10 \text{ Log } 270 - 10 \text{ Log } 54000 \text{ seconds} \\ &= 90 + 24.3 - 47.3 \\ &= 67.0 \end{aligned}$$

and the nighttime equivalent, Ln, would be 59.7:

$$\begin{aligned} \mathrm{Ln} &= \mathrm{SEL} + 10 \text{ Log } N - 10 \text{ Log } T \\ &= 90 + 10 \text{ Log } 30 - 10 \text{ Log } 32{,}400 \text{ seconds} \\ &= 90 + 14.8 - 45.1 \\ &= 59.7 \end{aligned}$$

If the study area has a background noise level of 60 Ldn, a fractional impact of .41 is obtained ($68.2 - 60 \div 20 = .41$). If the gross population of 3,600 is applied, 1,476 noise units are obtained. However, a "population equivalent" may also be determined by multiplying the actual occupancy of the study area by the fraction of a day observed, and totaling the products. For example, the daytime period (7 AM to 10 PM) is 15 hours long or $15/_{24}$ of one day. Similarly, the night period is $9/_{24}$ of one day. Thus, in the example, the population equivalent is determined by:

$$\begin{aligned} P &= (15/_{24} \times 1600) + (9/_{24} \times 3600) \\ &= 1000 + 1350 \\ &= 2350, \end{aligned}$$

and total noise units are determined by 2350 x .41, or 964.

This deviation is particularly interesting when a curfew option is examined. Assuming no operations after 10 PM and a shift of all curfewed operations to the daytime period, Ldn is reduced from 68.2 to 65.4, and fractional impact changed from .41 to .27. With a daytime equivalent population of 1,000, 270 noise units result (.27 x 1000 = 270). If the gross population of 3,600 is used, 972 noise units remain (.27 x 3600 = 972) after the curfew.

To be technically correct, the population equivalent during the day should be examined fro the daytime average sound level, Ld, and during the night for the nighttime average sound level, Ln, while assuming a 10 Leq reduction in background noise level for the night period. Under these conditions, the daytime fraction impact is determined by 67.0 - 60 ÷ 20 = .35, and the nighttime fractional impact is determined by 59.7 - 50 ÷ 20 = .485. Applying the day (1000) and night (1350) population equivalents, 350 and 655 noise units are obtained, respectively, for a total of 1005 noise units. Applying the curfew option results in a slight increase in daytime operations and 375 noise units.

Thus, the actual occupancy of the study area for day and nighttime periods is an extremely important variable, especially when a curfew option is considered, and the reviewer should be cognizant of the possible range of deviations which may result from such variables, as exemplified by the summary table of the previous example:

	TOTAL NOISE UNITS	
	No Curfew	Curfew
Ldn and gross pop.	1476	972
Ld + Ln and equivalent population	1005	375
Ldn and equivalent pop.	964	270

B. Planning Processes and Land Use Controls: A Direct Approach to the Forecasting Problem.

Forecasting the actual development which will generate variations in population and occupancy is an extremely difficult task which may be greatly simplified where the reviewer applies the tests of completeness and reasonableness noted in the section concerning air travel demand forecasting.

The completeness of land development forecasts should be judged on the basis of the "land use guidance evaluation procedure" which follows, i.e., the review should determine whether the analysts' discussion and presentation of the pertinent details concerning the developmental disposition of effected land in the airport noise impact zone is adequate. Reasonableness may be determined by the importance or weighting given by the analyst to various degrees of commitment made by appropriate decision-makers to control the use of land in a specified manner. For example, the following outline suggests a convenient method for evaluating and presenting important land use planning and control indicators:

LAND USE GUIDANCE EVALUATION PROCEDURE

1. Determination of extent and locus of authority

    a. Identification of jurisdictions by name and geographic limits

    b. Identification of specific planning and land development control authorities including:

        1. those available as a matter of administrative discretion

        2. those requiring promulgation of new regulations (ordinances)

        3. those requiring new legislation (from state, or national level)

2. Specification of Planning Powers

    a. Comprehensive or "master" planning authority, including such elements as

        - land use
        - circulation
        - community facilities

    b. Areawide or regional planning authority and the relationship to state and local governmental powers.

    c. Special purpose planning authority, including the power to adopt plans for transportation, water, sewer, institutional and economic development on an inter- or intra-jurisdictional basis.

    d. Environmental Planning authority including:

        - preservation of natural resources
        - prevention or remedy of air and water contamination
        - protection from hazardous environments
        - preservation of historic resources

3. Inventory of Land Development Status

   a. Undevelopable land, including

      - flood plains
      - earthquake zones
      - parks or wildlife refuges
      - areas of extreme slope

   b. Undeveloped land - land considered developable but lacking sufficient market interest to bring about conversion. Indicators include

      - stable or decreasing tax assessment
      - no applications for development permits (building, etc.) or changes of zoning

   c. Developing land - land which may or may not show evidence of construction but which will reflect the presence of market factors such as those suggested in (b.) above.

      - increasing tax assessments
      - applications for zoning changes
      - applications for development or construction permits
      - planning for or construction of infrastructure such as roads, water and sewer lines, electric power facilities, etc.

      One of the most important signs of developing land occurs when the tax assessment on a parcel of land is greater than that of other parcels showing the same land use (i.e., an assessment at levels applicable to developed land in the region when the parcel in question continues in agricultural use.)

   d. Developed land - developed land is generally well fragmented into discrete parcels which are occupied by manmade structures.

      Where further subdivision of land is possible without redevelopment (razing of structures), it should be considered <u>developing land</u> to the extent that the characteristics mentioned in (c.) above are present.

   e. Redeveloping land - redeveloping land has generally reached the status of developed land but reuse of the property is likely to require the actual demolition or modification of structures. Rehabilitation of structures, whether privately or publically financed, should not be construed as redevelopment unless a change in use or higher occupancy ratios are likely to result.

4. Land Use Controls

For each governmental entity described in Section 1, the analyst should determine whether or not its authorities include the following land use and development controls. In addition, a determination should be made of the nature of the existing land use controls being exercised, for each category, and whether such controls are likely to be effective.

a. Regulation - exercises of the police power

1. zoning

    a. cumulative
    b. noncumulative
    c. incentive ordinances (planned districts)
    d. conditional use provisions
    e. performance standards

2. subdivision regulations

    a. site plan review
    b. in lieu payments
    c. front foot benefit charge
    d. fees

3. housing codes

    a. acoustical performance standards
    b. code enforcement

4. building codes

    a. acoustical performance standards
    b. occupancy permits

5. official mapping

    a. highways
    b. terminals
    c. utilities
    d. parks
    e. statuatory time limitations

6. title recording

    a. flood plains
    b. easements
    c. noise labeling
    d. other hazardous environments

7. statuatory nuisance

    a. noise emissions

8. development districts

9. development rights

b. Acquisition and Disposition of Public Lands

1. condemnation

    a. public purpose definition-eminent domain
    b. public purpose definition-expenditure of public funds

2. leasebacks

3. sellbacks

    a. with covenants
    b. with easements

4. easements

    a. use easements
    b. right to trespass
    c. right to make noise
    d. right to nuisance

5. land trades

6. excess condemnation

    a. remnant authority
    b. restrictive authority
    c. recoupment authority

7. advanced acquisition

8. "quick taking" and triple bonding

c. Monetary and Fiscal Incentives and Controls

1. special tax districts

    a. development districts
    b. interjurisdictional tax sharing

c. 2. land banking
    - a. property tax deferral
    - b. payment of back taxes for reuse

3. transfer payments
    - a. exemptions
    - b. deductions
    - c. differential assessed values
    - d. differential tax rates
    - e. special assessments

4. annexation and consolidation

5. bonds and bonding limitations
    - a. revenue
    - b. general obligation
    - c. tax exempt interest

6. loans
    - a. community infrastructure
    - b. industrial development
    - c. residential development

7. grants
    - a. community infrastructure
    - b. industrial development
    - c. residential development

8. guarantees
    - a. mortgage insurance
    - b. interest rates
        - 1. guaranteed interest
        - 2. subsidized interest

9. fees

d. Capital Improvements

1. water and sewer
    - a. permits
    - b. licenses
    - c. performance standards
    - d. capital financing
    - e. operational financing

d. 2. transportation facilities

   a. collector streets
   b. arterials
   c. limited access
   d. mass transportation facilities
   e. vehicle storage

   3. utilities

   a. permits
   b. licenses
   c. performance standards
   d. capital financing
   e. operational financing

e. Contractual Agreement

   1. between public entities

   2. between public and private entities

   3. between private entities

SAMPLE WORKSHEET FOR ESTIMATING FUTURE POPULATION*

STUDY AREAS	STATE A							FEDERAL			
	3	4	5	19	31	33	34	19	31	33	34
Planning Powers	• SPECIAL PURPOSE — WATERSHED • ENVIRONMENTAL — FLOOD PLAIN										
Land Development Status ** Status Category	B	E	D	E	B	C	C				
Exercised Land Use Controls • Regulatory					FLOOD PLAIN	OFFICIAL MAP - STATE HIGHWAY		HUD 1390.2 DISCRETIONARY	FPIC FLOOD PLAIN	HUD 1390.2 DISCRETIONARY	HUD 1390.2 UNACCEPTABLE
• Acquisition & Disposition			AQUISIT. FOR PARK			60% SITE TAKING 3-5 YEARS					
• Monetary & Fiscal					NO INSURANCE					NO VA OR FHA MORTGAGE INSURANCE	
• Capital Improvements						HIGHWAY, CLOVER LEAF + EASEMENT 5-7 YRS					
• Contract											

* Counties A & B (on the following page) are within State A, etc.

** A = Undevelopable B = Developable C = Developing
D = Developed E = Redeveloping

SAMPLE WORKSHEET FOR ESTIMATING FUTURE POPULATION

STUDY AREAS	COUNTY A						COUNTY B						
	1	2	3	4	5	6	18	19	30	31	32	33	34
Planning Powers	• COMPREHENSIVE - 1972 ADOPTED						• COMPREHENSIVE - CURRENTLY BEING REVISED						
Land Development Status Category	C	B	B	E	D	D	E	E	B	B	B	C	C
Exercised Land Use Controls • Regulatory *	CUMULATIVE ZONING, BUILDING CODES R1	R5	R18	M	R1	R5	NONCUMULATIVE ZONING, SUBDIVISION REGS., HOUSING + BUILDING CODES C	C	Ag	Ag	Ag	R5	R5
• Acquisition & Disposition				LEASED FOR INDUST. PARK									
• Monetary & Fiscal									AGRICULTURAL USE TAX RELIEF LAND RESERVE				
• Capital Improvements	SEWER + STORM DRAIN $1.8 MILLION 2-3 YRS.		COUNTY ROAD EXTENTION 2-3 YRS.									WATER + SEWER $1.4 MILLION 3-5 YEARS	
• Contract									AGRICULTURAL USE COVENANT ON ALL PROPERTY				
Population by Principal Permitted Use • Existing	15	26	0	0	260	614	0	0	4	16	9	240	312
• Forecasted	180	300	1000	0	260	614	0	0	4	16	9	1100	1600

* R1, R5, etc. refer to zoning categories.

Note that in Section 1, the reviewer may determine from the E.I.S. the basic geographic and legal limits of jurisdictions with actual or potential authority to control land use. In Section 2, the specific power to plan is depicted for each jurisdictional entity described in Section 1. Then in Section 3 land presently or potentially impacted by aircraft noise is conveniently sorted into four categories which may be subsequently evaluated utilizing the existing land use controls exercised by governmental entities described in Section 1.

Up to this point, the reviewer may decide that the E.I.S. is complete, but the analyst's assumptions concerning the potential effectiveness of various land use controls in different situations should certainly be scrutinized for reasonableness. For example, in a study area which is largely comprised of undeveloped and developing land which is both planned and zoned for agricultural use, but for which speculative pressures (e.g., high tax valuation for a limited use) and inconsistent planning practices (e.g., granting of changes in zoning, and/or building of supporting water and sewer facilities), the reviewer should be cognizant of the fact that the existing zoning will do little or nothing to prevent development, regardless of the good intentions voiced by the local governing body; the assumption by the analyst that the area would remain agricultural would be unreasonable, and that portion of the statement inadequate.

Another area which must be scrutinized is concerned with whether specific jurisdictional entities have the authority to exercise a proposed land use control, and, most importantly, what degree of authority is available under existing legislation. The assumption that a governing body or agency has the authority to acquire land or rights in property for specific purposes; to regulate the use of land in a prescribed manner; or to prospectively employ monetary, capital improvement, or contracturel controls for the purpose of achieving compatible land usage is one which must clearly and unequivocally be a matter of administrative discretion. Where such controls are to be applied pursuant to the promulgation of regulations or new enabling legislation, the assumption that they will actually be applied is unreasonable. In cases where the analyst has failed to provide the reviewer with information of sufficient detail for the reviewer to determine whether such assumptions are reasonable, the E.I.S. should be considered inadequate and incomplete.

Formal adoption of a comprehensive land use plan by a local governing body establishes a very important legal precedent because of the general rule that zoning must be in conformance with the directions of the comprehensive plan. The comprehensive plan is both a policy statement and a research document, intended to commit local land use decision-makers to a logical sequence of response to development pressures. The responses must be grounded in fact and a rigorous analysis of policy alternatives.

E.I.S. reviewers should be especially sensitive to situations where the authority to zone is not linked to a comprehensive land use planning document. The absence of the guiding document makes much easier an arbitrary zoning change in response to narrowly based pressures. The existence of the planning document permits the proprietor to challenge openly any change in zoning which is not in conformance with the plan. In situations where any of the jurisdictions in the airport impact area have neither zoning nor planning powers the analyst should be required to contact an appropriate State agency to determine whether land use plans and controls have been developed or applied exogenously. The increase in State interest in land use planning and development controls and the resultant declaration of airports as areas of special regional and State concern should provide both analysts and reviewers with more accurate tools for the determination of future land useage than have been available.

C. Gross Planning Indicators

Application of the guidance system explained above is simplified if the analyst provides the reviewer with certain clues to the land development process and the related pressures. Private and public investments often carry implied consequences which greatly expand the land use impacts of the original action. Too often these consequences are not understood when the impact of the action is first considered and the public and private costs of the consequences far exceed the benefits in the long term.

Public investments in infrastructure, such as highways, and water and sewer treatment networks must be analyzed in this light. Highway access to an airport, a factory, a shopping center and other such centers of activity will create, automatically, pressures for development all along the access road such that land conversion is a foregone conclusion.

THE REVIEWER MUST REMEMBER THAT RESIDENTIAL DEVELOPMENT IS BY FAR THE LARGEST CONSUMER OF URBAN AREA LAND, AND THE ONLY LAND USE THAT CAN EASILY FILL IN THE SPACES BETWEEN COMMERCIAL, INDUSTRIAL OR RECREATIONAL ACTIVITY CENTERS.

Thus when linear networks are created by investment in public facilities, they will attrack residential uses primarily, with proportionately insignificant quantities of uses more compatible with airport activities.

Similarly, private investment in activity centers such as factories, industrial parks, recreational facilities or commercial centers will attract both residential concentration and public investment. Major private investment, in fact, will not be made until the supporting public facilities are guaranteed. Subsequently, the very existence of the combination of private and public investment will attract residential development to take advantage of proximity to the facility. Since World War II, airports themselves have provided one of the best examples of this pehnomenon.

The analyst preparing an E.I.S. must present a clear picture of the plans for public investment in the impact area. Obtaining private investments plans is a more difficult task. It is for this reason that an adequate base of local land use planning and control is so important. There are other clues which can be detected, however, which will provide individuals reviewing an E.I.S. with a better idea of the development plans for a given area. Perhaps the best is land ownership.

1. land ownership

Land ownership records are a matter of public record, though they require detailed examination of plat books and tax records on file with local government authorities. Analysis of land ownership records by E.I.S. analysts will turn up efforts to amass large tracts of land.

2. land prices

These records require equally diligent research by the analyst as does analysis of land ownership, though often they can be combined. Substantial increases in the price of land often provide evidence of acceptance of the area under study as suitable for a more intense use and, therefore, worth a higher investment.

3. petitions for zoning change

Mentioned earlier as an essential component of the land use monitoring system, the zoning change, also a matter of public record, will telegraph the anticipated future use, at least to the extent of implying more intense use, with the accompanying need for supporting public facilities.

In summary, environmental impact statements at a minimum, should contain evidence that land ownership, land value, and zoning procedures have been carefully analyzed with the consequences for public and private land development impact in mind.

D. Indigenous Noise Impact ("Background Noise")

One aspect of land development and its relationship to airport operations an impact which has, until recently, not received proper attention is the noise generating character of certain types of land use. The highly specific identification of aircraft noise has permitted people to believe that aircraft, (or an occasional truck or motorcycle) are the cause of changes in environment from "peaceful" to "noisy." Certain types of land development bring with them long term noise impact which may well remain at levels above those generated by all but a very few overflying aircraft. Early analysis of neighborhood noise levels suggests that background levels ranging from 60 to 65 Ldn are quite common in residential neighborhoods not impacted by a major freeway, airport or specific ground source.

Among the best recognized generators of background noise is the automobile. Concentrations of automobile activity, such as shopping centers, will also result in increases in background noise levels. Heavy industry, mining operations and truck traffic may also be major contributors, particularly if they run during the evening and night hours. Amusement facilities including outdoor theaters, swimming pools, rides, and race tracks, will also have to be considered, though in some cases their noise making properties are strictly limited to certain days of the week or hours. The standard subdivision will generate substantial background noise, with levels generally varying with population density and vehicle ownership.

It seems more and more likely that measurement of the noise impact of airport operations will be placed in the context of the background noise of affected communities, and that plans and programs to reduce noise exposure will require a broadly based analysis of all noise sources. An overview of the noise sensitivity of certain land uses is shown in the Figures S and T which follow. At present these sensitivities are reflected in one Federal Government Regulation only: HUD Circular 1390.2 which regulates the use of Federal mortgage programs with respect to noise levels.

TABLE IV
NOTES FOR FIGURE S

☐	▧	▨	■
Clearly Acceptable	Normally Acceptable	Normally Unacceptable	Clearly Unacceptable

Clearly acceptable: The noise exposure is such that the activities associated with the land use may be carried out with essentially no interference from aircraft noise. (Residential areas: both indoor and outdoor noise environments are pleasant.)

Normally acceptable: The noise exposure is great enough to be of some concern, but common building constructions will make the indoor environment acceptable, even for sleeping quarters. (Residential areas: the outdoor environment will be reasonably pleasant for recreation and play.)

Normally unacceptable: The noise exposure is significantly more severe so that unusual and costly building constructions are necessary to ensure adequate performance of activities. (Residential areas: barriers must be erected between the site and prominent noise sources to make the outdoor environment tolerable.)

Clearly unacceptable: The noise exposure at the site is so severe that construction costs to make the indoor environment acceptable for performance of activities would be prohibitive. (Residential areas: the outdoor environment would be intolerable for normal residential use.)

[1] Standard Land Use Coding Manual.

[2] Noise Sensitivity Code (see page 53).

[3] x represents SLUCM category broader or narrower than, but generally inclusive of, the category described.

[4] Excluding hospitals.

Source: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of Housing and Urban Development. Government Printing Office, Washington, D.C., Nov. 1972; pp. 54/55.

FIGURE S
LAND USE COMPATIBILITY GUIDELINES FOR
AIRCRAFT NOISE ENVIRONMENTS

LAND USE CATEGORY	SLUCM[1] CODE	NSC[2]
Residential - Single Family, Duplex, Mobile Homes	11x[3]	1
Residential - Multiple Family, Dormitories, etc.	11x, 12, 13, 19	1
Transient Lodging	15	2
School classrooms, Libraries, Churches	68 7111	1
Hospitals, Nursing Homes	651	1
Auditoriums, Concert Halls, Music Shells	721	1
Sports Arenas, Outdoor Spectator Sports	722	1
Playgrounds, Neighborhood Parks	761, 762	1
Golf Courses, Riding Stables, Water Rec., Cemeteries	741x, 743x, 744	2
Office Buildings, Personal, Business and Professional	61, 62, 63, 69, 65[4]	3
Commercial - Retail, Movie Theaters, Restaurants	53, 54, 56, 57, 59	3
Commercial - Wholesale, Some Retail, Ind., Mfg., Util.	51, 52, 64, 2, 3, 4	4
Manufacturing, Communications (Noise Sensitive)	35, 47	2
Livestock Farming, Animal Breeding	815, 816, 817	3
Agriculture (except Livestock), Mining, Fishing	81, 82, 83, 84,85,91,93	5
Public Right-of-Way	45	5
Extensive Natural Recreation Areas	91, 92, 93, 99,7491,75	3

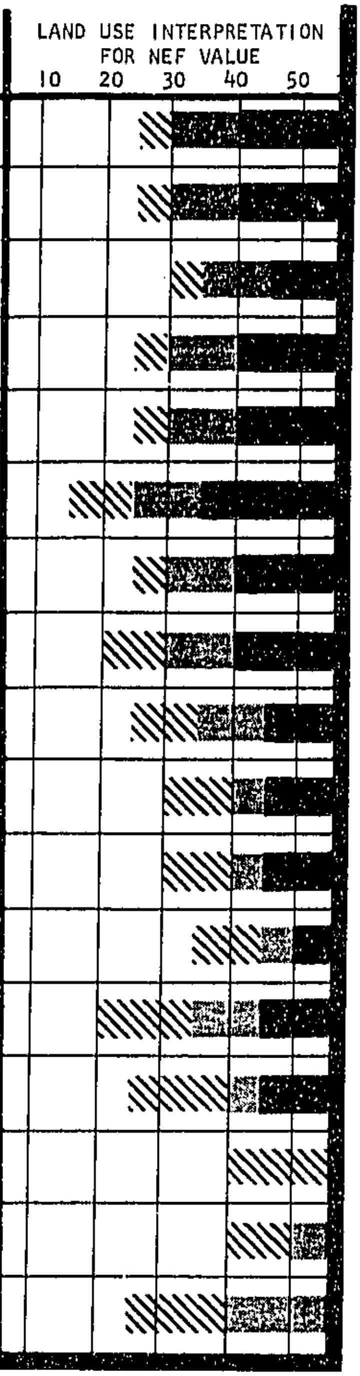


FIGURE 7
NOISE IMPACT ON HUMAN ACTIVITIES

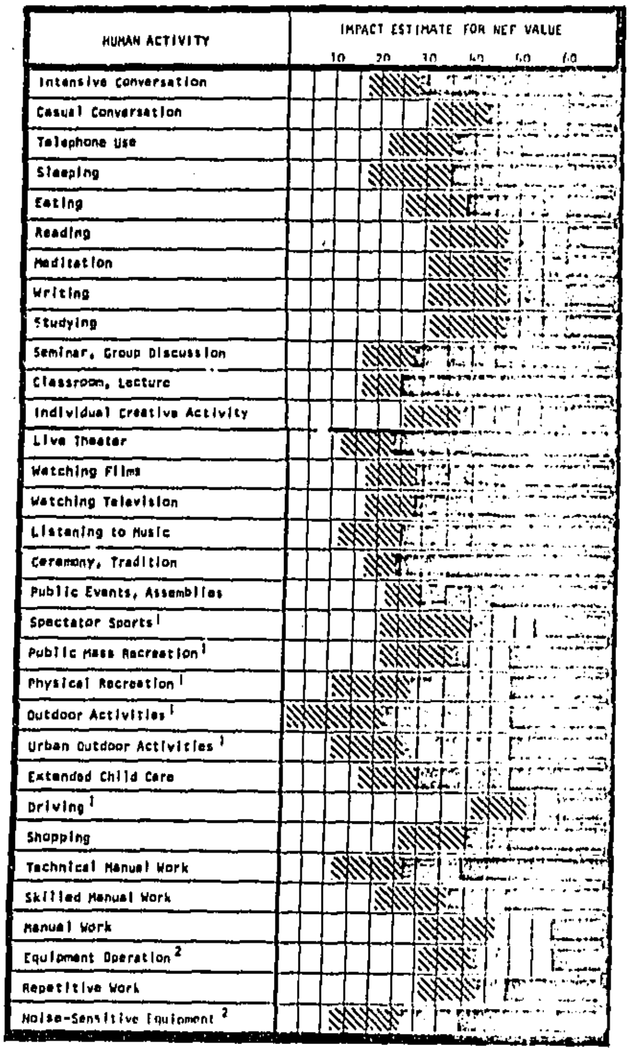
Low Impact: Activity can be performed with little or no interruption from aircraft noise, though noise may be noticeable above background levels.

Moderate Impact: Activity can be performed but with some interference from aircraft noise due to level or frequency of interruptions.

Serious Impact: Activity can be performed but only with difficulty in the aircraft noise environment due to level or frequency of interruptions.

Critical Impact: Activity cannot be performed acceptably in the aircraft noise environment.

Impact estimates based on activity criteria of Figure 2-16 and methodology developed in Figures 2-18, 2-19 and 2-20, for noise environment with 64 day and 8 night operations.



[1] No allowance for structural insulation.

[2] Depends on characteristics of particular equipment.

SOURCE: Aircraft Noise Impact Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; pp. 61/62.

FIGURE T
NOISE IMPACT ON HUMAN ACTIVITIES

☐ Low Impact ▨ Moderate Impact ▓ Serious Impact █ Critical Impact

Low Impact: Activity can be performed with little or no interruption from aircraft noise, though noise may be noticeable above background levels.

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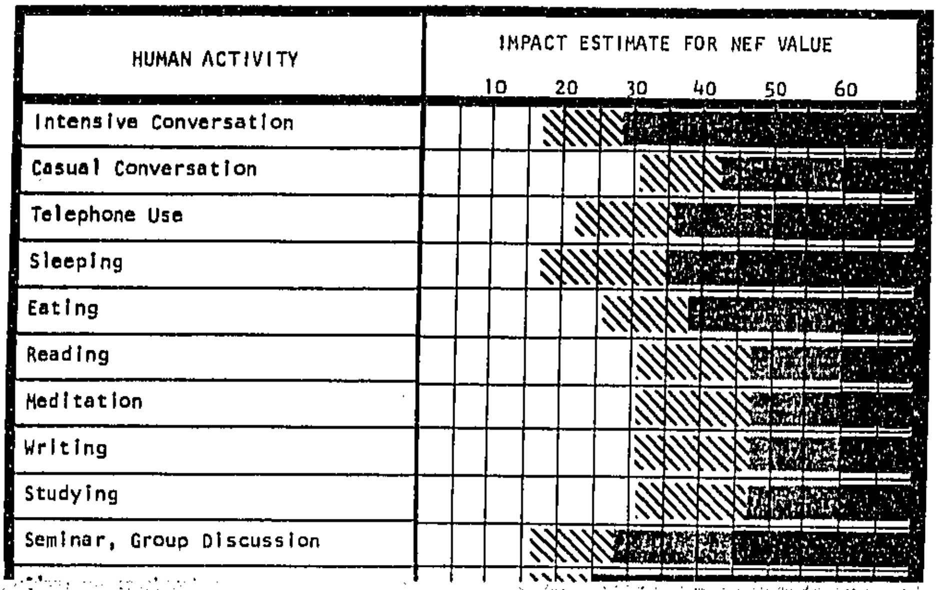
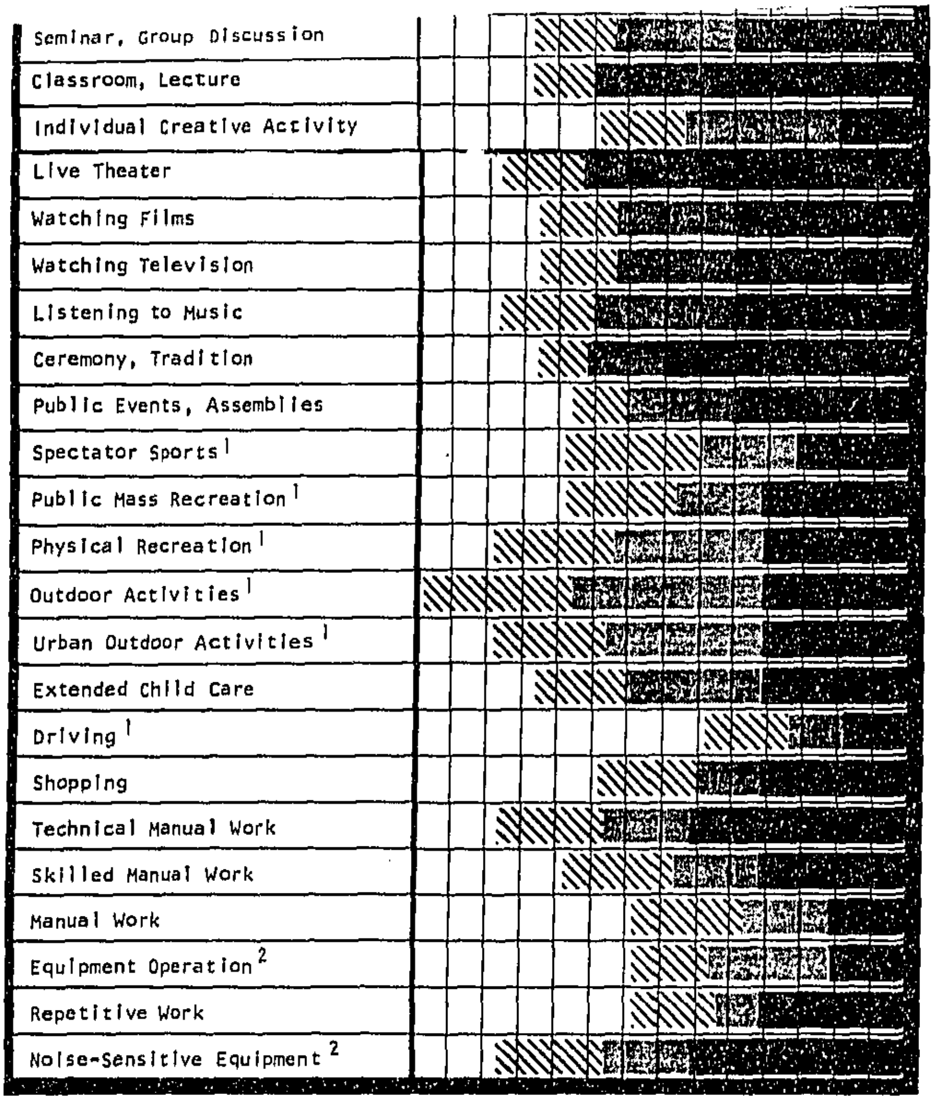
Impact estimates based on activity criteria of Figure 2-16 and methodology developed in Figures 2-18, 2-19 and 2-20, for noise environment with 64 day and 8 night operations.





[1] No allowance for structural insulation.

[2] Depends on characteristics of particular equipment.

SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; pp. 61/62.

ALTERNATIVES TO PROPOSED FEDERAL ACTIONS AND THE RELATIONSHIP TO NOISE ABATEMENT STRATEGIES

Environmental Impact Statements relating to airports and airport operations are most likely to result from efforts to develop new facilities or expand existing ones. These E.I.S. generating actions are listed in Figures G and H combined. Federal assistance for these actions is controlled by the Airport and Airway Development Program (ADAP). The interrelationship of these actions will, in most cases, be close. Expansion of operating capacity by runway adjustments to permit larger aircraft, for example, will require subsequent, if not concurrent adjustments to terminal facilities, parking capacity, access to the metropolitan area and other improvements to supporting infrastructure. In almost all cases the development program will use a combination of local and Federal financing, with the local component being drawn from airport revenues or, in the case of large projects, bond sales. Thus the reviewer must consider the feasibility of the financial program to be applied, particularly as it relates to the staging of work.

The most ciritical alternative to be considered for a major Federal action which increases capacity is that of assigning projected "excess" operations to another existing facility serving the same economic trade area. In some instances, joint use of military airfields may be an especially important consideration becasue additional air carrier operations will rarely contribute a substantial increase to noise levels generated by fighters, bombers and heavy transport military aircraft if the base is moderately active.

Conversely, the most critical alternative to be considered where a new airport is proposed, is the expansion of an existing airport or airports serving the same economic trade area. Additional instrumentation and a reduction in the number of general aviation operations (particularly by those aircraft which cannot approach and depart at speeds identical to air carrier jets) may double or triple the capacity of a congested airport. Where separation standards may be met, the addition of a main ILS runway can also substantially increase capacity.

Clearly, such development program alternatives must be tied to a noise prevention or abatement plan to be considered an adequate analysis of environmental impact. Table V provides a comprehensive review of noise abatement strategies and their salient characteristics. The airport related actions mentioned in the paragraph above, however, will be made much more environmentally sound if they are programmed with such strategies in mind, and in concert with the appropriate governmental agencies.

Figure U provides a matrix of interrelationships between noise abatement strategies and the variety of governmental agencies holding significant authority. Figure V expands on the interrelationships between abatement strategies, showing whether one approach has a positive or negative impact on another. These matrices, while complex, are very helpful in setting airport development alternatives into perspective with the complementary actions which are essential if the effects of airport noise impact are to be properly recognized and minimized. A final graphic presentation, Figure W suggests some of the timing constraints of certain noise abatement strategies, a vital consideration in reviewing alternative development plans and assessing environmental impact.

TABLE V

NOISE ABATEMENT STRATEGIES: COSTS, EFFECTIVENESS, OTHER CONSIDERATIONS

Noise Abatement Strategy	Noise reduction[1]	Costs	Limitations, Comments, other considerations
Higher holding and maneuver altitudes, raise glide slope intercept altitude	About 9 EPNdB with increase from 1500' to 3000'. Primary benefit 2-4 miles from threshold.	ATC workload	In use at some airports. FAA policy "keep 'em high". Doesn't help in highest noise areas. No equipment change.
Steeper glide slope	0-10 EPNdB, greater with greater distance from threshold. (higher altitude, reduced power)	Pilot workload Safety	Some gains available from enforcing existing minimum glide slope. Reduce fear of low-flying aircraft.
Two-segment approach. 6° to 3° at 3 miles, 1000' altitude.	0-10 EPNdB, greater with greater distance from threshold. (higher altitude, reduced power)	Safety Pilot workload	Could have later switch to flatter slope with automated systems.
Two-segment approach. 6° to 3° at less than 1 mile, 250' to 400' altitude. (automatic controls)	5-15 EPNdB, greater with greater distance from threshold. (higher altitude, reduced power)	Equipment modifications	More benefit in highest noise impact areas than most other changes.
Delayed flap and gear extension	0-6 EPNdB until extension (reduced power)	Safety Pilot workload	Considerable benefit from changes with existing equipment - pilot option now. More potential with automated systems. Potential benefit in high-noise areas.
Combined approach techniques, existing equipment (high intercept, reduced flaps, 2-segment approach)	Possibly 20 EPNdB at 6-10 miles, less as threshold approached. (higher altitude, reduced power)	Pilot and ATC workload Safety	
Thrust cutbacks after takeoff, reduced flaps.	Up to 5 EPNdB[1] after cutback, less with greater distance. Varies with aircraft type.	Safety	Now in use at some airports and by some airlines. Less useful with 4-engine jets because of less reserve power. More potential with higher reserve power. Some additional potential with automated systems. May result in more area in NEF contours because of slower climb after cutback.
Preferential runways	Raises in some, lowers in others	Small to moderate reduction in capacity, Pilot & ATC workload, Longer flights	Opportunity limited by land use pattern, usefulness limited by wind conditions at airports with strong prevailing winds.
Runway threshold shifts	Slight	May involve runway extension	Much shift required for significant reduction. More important as other techniques implemented. May increase airport noise with increased use of thrust reversal.
Concentration in corridors, delays before turning.	Varies, increase in some areas	Reduced capacity Pilot and ATC workload Longer flights	Monitoring helpful. Once established, should remain stable to be useful in adjusting land uses to noise impact.

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[1] Data for operational changes from M. C. Gregoire and J. M. Streckenbach, Effects of Aircraft Operation on Community Noise, Seattle, The Boeing Company, June 1971. Will vary considerably depending on existing practice, type of aircraft used, and ground location relative to flight path.

TABLE V (CONT)

Noise Abatement Strategy	Noise reduction	Costs	Limitations, Comments, other considerations
[1]Housing code	Inside: up to 25 EPNdB over normal construction	Administrative Code writing Increased development costs	Housing code commonly applies to existing dwellings. Public concern legally questionable for requirements in single-family dwellings. Many jurisdictions involved. Local opposition to increased costs. Model codes helpful.
Sound insulation of structures	10-25 EPNdB over normal construction. Varies with type of existing construction and extent of modification.	Varies with reduction: 10-15 dB, about $3/sq. ft.; 25 dB, about $8/sq. ft. (residences)	Doesn't change outdoor environment. Air conditioning required - changes "feel" of being inside house - ability to hear children and other neighborhood noises. Also insulates against traffic and other ambient noise. Legal limits on imposition of requirements through zoning and building codes - state enabling legislation, model codes helpful. Resistance from local community - increases development costs. Can tie provision of public funds to granting easement.
Sound masking	None - increases noise level	Acquisition, installation (varies)	Untested in residential use. May be suitable for some commercial facilities.
Planning by government, airport authority	Reduce sensitive area exposed	Administration Data collection	Must be based on accurate information for long time horizon to be effective in land use planning. Needs implementation tools. Many local jurisdictions often involved.
Public Hearings	Varies	Varies	Low level of public information makes process one-sided. Could be required for larger number of noise impact factors, including operational changes as well as location and design. Little incentive to adopt public-recommended changes.
Public involvement	Varies	Higher than hearings	Meaningful citizen involvement in decision-making expensive and time-consuming. Needed earlier in design process. May only reach certain socio-economic groups. Need some means to require joint solution to make effective (airport may ignore).
Noise easements on developed property	None	Varies with extent of easement - same order of magnitude as insulation - 10-20% of value.	Does nothing to control noise. Effect may depend on method of financing. May provide enough money to insulate structure. May be purchased or leased. Protects airport operator against litigation, though increased noise may bring new litigation.
Tax reductions	None	Administrative decision determines amount of tax loss	Similar to easement, but doesn't give legal protection. If applied to new development, may encourage incompatible development.
Existing legal channels	Varies	Litigation cost	Difficulty of demonstrating extent of damage. Must be continuing threat in order to affect aircraft noise levels. Same people often on both sides of case when city vs. airport authority. Time for settlement long.
Regulation by FAA	Varies	Costs to airport operator, airlines	FAA has little incentive to consider local community impact. Regulations to be most effective should be based on performance standards, but such standards make enforcement difficult. Difficult to develop regulations that don't create unusual market forces rather than desired noise reduction. Not automatic compliance, depends on enforcement.

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[1] *MANAPS*, JFK International Airport, p. 17.

TABLE V (CONT)

Noise Abatement Strategy	Noise reduction	Costs	Limitations, Comments, other considerations
Relocation of incompatible uses - Acquisition	Reduce sensitive area exposed	Very high - purchase of developed land, demolition, assembly and preparation, relocation. (Federal aids for many parts of program)	Airport authority often not authorized and would not want to undertake. Generally very large areas involved. Local opposition probably strong. Existing development may not have sufficient other "blight" to justify. Noise as blighting influence in itself sufficient to justify redevelopment only in most extreme cases. Some relocation may be done in private sector if market is aided - alternatives provided, relocation loans, etc.
Relocation - market service	Reduce sensitive areas exposed	Varies with nature and extent of program. Relocation information and/or financial assistance. Development of alternate locations.	Doesn't reduce noise level. Theoretically means of adjusting market efficiently.
Zoning to compatible use	Reduce sensitive area exposed	Administrative. Slows development if demand for forbidden use (tax loss). Opportunity cost of land in other uses. Retroactive - compensation. If a "taking" - acquisition. Federal aids (HUD 701).	Usually many jurisdictions have authority in impact area. Local government doesn't have resources to set and enforce complex standards. Easier with model codes. May require enabling legislation to use noise as criterion. Can't restrict aircraft operations (Federal preemption). Tax competition discourages restrictions. Not retroactive - limited to undeveloped areas. Local government will resist metropolitan zoning. Minnesota Airport zoning act provides for combined authority for standard setting. Zoning-oriented land use classifications and noise sensitivity not always correlated - new standards may be required.
Subdivision regulation	Reduce sensitive area exposed	Administrative	Require large parcels for commercial/industrial development in impact area. Little effect in itself in reducing conflicts - dependent on zoning regulations.
Public Services Planning - Official Map (Withhold services in impact area)	Reduce sensitive area exposed	Administrative. Tax income loss from undeveloped land. If a "taking" - acquisition.	May be legal restrictions on ability to withhold services. State enabling legislation required. May be followed as informal policy, but with much reduced effectiveness.
Advance acquisition of land in impact area for resale with controls	Reduce sensitive area exposed	May be very high initial cost and carrying cost, considerable recovery with development.	Due to high cost, limited to undeveloped areas. Legal authority limited - state enabling legislation required. Airport authority not likely to undertake unless required to. Political opposition from local government. Tax competition. Limited by financial resources. Income highly dependent on timing. Acquisition may be difficult because of speculative increases in value after site selection. New airports only. Method to circumvent limitations on use of noise criteria in zoning and building codes through deed restrictions.
Building codes requiring insulation	Inside: up to 25 EPNdB over normal construction	Administrative. Increased costs of development (tax loss) 10-20% increase in construction cost.	May require state enabling legislation to use noise zones for building code restrictions. Difficult to apply retroactively. Model codes helpful. Local opposition to increased development costs. Not likely to be legally applicable to single-family residences. Many local jurisdictions involved. Heat insulation often does not provide adequate sound insulation. Cost to owner or buyer.

TABLE V (CONT)

Noise Abatement Strategy	Noise reduction	Costs	Limitations, Comments, other considerations
Relocation of takeoff and approach routes	Raises in some, lowers in others	Longer flights Reduction in capacity Pilot and ATC workload	Opportunity limited by development pattern. To preserve opportunity need development controls in undeveloped corridors. Monitoring helpful.
Schedule restrictions (eliminate night flights)	High at night, none in daytime.	High to airlines if no alternate airport. Reduced capacity. Schedule conflicts.	Doesn't help at schools, other day uses. Considerable benefit in residential areas. Greatest opportunity in metropolitan areas with more than one airport, outlying airport for night flights.
Shifting corridors by time of day	Varies, increase in some areas and at some times	Reduced capacity Pilot and ATC workload Longer flights	Monitoring helpful. May be particularly useful in unusual land use situations where day-night shift appropriate. Possibility of providing some respite for all but closest in areas at cost of wider area of impact.
Aircraft type restrictions. Eliminate 4-engine jets, license by noise levels.	Varies with existing usage, particular restriction.	High to airlines if no alternate airport.	In use at JFK; Newark and La Guardia no 4-engine jets. Greatest opportunity in metropolitan areas with more than one airport, outlying airport for noisier aircraft.
Regulate time and place of ground operations	Varies		Most benefit from restricting night engine runups near residential areas.
Nacelle Lining	Takeoff - 3 EPNdB Approach - 10-15 EPNdB from present engines[1]	Initial - up to $1,000,000/aircraft, + 9% operating[1]	Available soon. Requires Federal action.
"Quiet engine"	About 10 EPNdB below "best" today (747, DC-10) takeoff and landing[1]	$4 million/aircraft retrofit, less on new aircraft[1] (varies with type)	Available in 1975 or later. Requires Federal action. Various types under consideration.
Airframe changes Larger aircraft V/STOL aircraft	Reduce number of flights, increase takeoff and approach slopes	Research and development	Private sector action. Limited by passenger traffic demand.
Traffic allocation among airports and aircraft.	Reduce sensitive areas exposed, reduce number of flights	Longer flights Schedule problems Ground transportation	Among airports - limited to areas with more than one major airport. Among aircraft - reducing surplus seating requires some inter-airline cooperation. Federal planning assistance.
New airports	Raises some, lowers others. Reduce sensitive area exposed.	Administration Planning Acquisition Access Externalities at different locations	Some regional cooperation likely to be required. Easier with metropolitan authority with taxing powers. Coordination of airport location and design with land use planning and controls necessary to insure long-run benefits. Federal planning assistance.
Abandonment of existing airports	Reduce sensitive areas exposed	Abandon existing facilities. Jobs lost if no new airport. Depends on distance to nearest available air facility.	Can possibly use for general aviation or V/STOL. Possible income from sale of property.
Airport master planning - runway orientation	Reduce sensitive areas exposed	Varies: Administration Acquisition Operating costs	Wind, safety factors now predominate design requirements. Limited incentive to consider noise. Helpful to coordinate with surrounding land use if under same authority. Primarily new airports, also expansion. Expansion of use of environmental impact statement and review requirements may cause noise to be considered. Federal planning assistance.

[1] National Academy of Sciences, National Academy of Engineering, Jamaica Bay and Kennedy Airport (Volume II), 1971, p. 115

TABLE V (CONT)

Noise Abatement Strategy	Noise reduction	Costs	Limitations, Comments, other considerations
Airport master planning - maintenance areas	Varies by location	Varies	Locate maintenance areas away from sensitive uses. Federal planning assistance.
Airport master planning - site size to include impact area	Reduce sensitive area exposed	May be very high initial cost, carrying costs. Taxes foregone. Acquisition (possible income from leasing or sale with restrictions)	Airport authority may not be legally empowered to acquire land for other than airport use. (State enabling legislation required.) Local political opposition - removal from tax rolls, development potential. Coming into use at newest planned airports; Palmdale (Los Angeles) 18,000-acre site; Irving (Dallas-Ft. Worth); Minneapolis-St. Paul. Limited by financial resources of airport authority. Can make agreements on controls with surrounding communities rather than purchase. Federal planning assistance.
Airport master planning - management of airport property	Reduce sensitive area exposed	Administration Possible reduced utilization	Conditional leases or sale of excess property. Effectiveness limited by site size. Federal planning assistance.
Air traffic demand - V/STOL	Reduce highest noise impact areas, possibly increase lower impact. (Reduce number of CTOL flights)	New metropolitan V/STOL ports. New equipment. Access.	V/STOL demand most sensitive to changes in other transport - highways, HSGT, etc. Introduce now unexposed areas to noise. High takeoff, approach noise. May be serious access and parking problems in downtown areas.
Other transport modes (Primarily High speed ground transportation)	Reduce number of flights	System, equipment, access, land acquisition, research and development, planning.	Inter-regional and inter-state cooperation required. Volume sufficient for major separate system in only very few locations (NE corridor, LA - SF).
Other technologies (communication)	Reduce number of flights	System Research and development	Unpredictable, 10-20 year + horizon. Social changes likely with communication system sufficiently developed to reduce flight demand. National scale of planning and implementation required.
Barriers	Up to 10 EPNdB adjacent to airport. Useful for runups	Varies with extent	High, massive barriers best. Trees limited in reduction capacity. Not effective for airborne aircraft. Barrier must be close to either source or receiver to be effective. May be useful for V/STOL.
Public acquisition and development of vacant land	Reduce sensitive areas exposed from what would occur without public action	Acquisition Site Preparation Marketing Carrying costs Administration Tax loss during holding period	Airport authority not likely to want to get involved. Local government may object to controls. Business objections to government in the development business. Limited by demand for compatible use in impact area. Significant percent of impact area only at a very few airports.
Market service incentives for compatible development of vacant land	Reduce sensitive areas exposed from what would occur without public action	Publicity Administration Tax incentives--tax loss for initial period	Can't prevent incompatible development. Tax incentives a minor factor in most business location decisions. Limited by demand for compatible use in impact area. Significant percent of impact area only at a very few airports.
Public use	Reduce sensitive areas exposed from what would occur without public action	Acquisition Development Differential in capital and operating costs between airport site and alternate sites Tax loss	Public uses likely to be limited. Federal aids available for many public uses. Many open space and recreation uses also sensitive to noise or other airport impact.

TABLE V (CONT)

Noise Abatement Strategy	Noise reduction	Costs	Limitations, Comments, other considerations
Legislative establishment of responsibility and payment mechanism	Varies	Cost to airport operator, airlines. Administration.	Powerful airline, airport and airframe manufacturer lobbies will oppose. Limited by Federal preemption of airline regulation, prohibition against state interference with interstate commerce. Legal questions about use of noise contours as basis of strategy.
Information systems, monitoring	Control over other noise abatement strategies	Setup of monitoring network. Administration	Must have legal powers to control aircraft in order to be useful. Provide information for setting local standards.
Alternative decision structures, Metropolitan coordinating mechanisms: a. cooperation b. joint authority c. supervening authority	Easier implementation of land use related strategies	Administrative	Simple information may be sufficient to achieve considerable control. Local objections strong to giving up any significant decision power to metropolitan authority. Needs to be combined with other measures, such as tax sharing, to encourage local participation.
Economic incentives for noise reduction: Fines Variable landing fees Passenger taxes Adjusting airline license fees	Varies	Costs to airlines. Monitoring system. Administration.	Must be carefully structured to have desired effect. Limited by Federal preemption of aircraft operations regulation, prohibition against state interference with interstate commerce. Possible conflicting incentives at different airports.
Information to local communities, developers, homeowners	May reduce sensitive area exposed from what would occur with no information	Cost of information Enforcement	Leaves decision on whether to use noise as criterion to individual or community. Any social costs of noise impact not included in decisions.

SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of Housing and Urban Development. Government Printing Office, Wash., D.C., November 1972; pp. 82-87.

POPULATION GROUP NOISE ABATEMENT STRATEGY	Impact area residents	Local community	Local planners	Local gov't	Metro govt, COG	Airport Authority	
Operational Changes	L / S	L / S	L / S	L / S	L / S	H / I	H /
Schedule Restrictions	L / S	L / S	L / S	L / S	L / S	H / I	H /
Aircraft Type Restrictions	L / S	L / S	L / S	L / S	L / S	H / I	H /
Technological Change	L / N	L / N	L / N	L / N	L / N	L / S	H /
Airport System Change	L / P	M / P	M / P	M / P	H / I	H / P	M /
Traffic Demand Change	L / I	L / I	L / T	L / I	L / I	L / P	M /
Encouraging Compatible Use	L / P	L / P	H / T	H / I	H / I	M / F	L /
Public Use	L / P	L / F	H / T	H / F	H / P	L / N	L /
Relocation of Incompatible Use	L / X	L / P	H / T	H / I	H / P	M / F	M /
Prohibiting Incompat. Use	L / X	L / P	H / T	H / I	H / P	L / N	L /
Sensitivity Changes	H / X	L / X	H / T	H / F	H / P	M / F	M /
Airport Environs Planning	L / P	L / P	H / I	H / I	H / I	M / P	L /
Compensation	M / P	L / F	H / T	H / I	H / I	M / F	M /
Legal Action	H / I	L / I	H / T	H / I	H / I	H / P	H /
Regulation, Admin. Mech.	L / S	L / S	L / S	L / S	L / S	H / I	H /
Metropolitan Control	L / P	L / X	M / X	M / X	H / I	H / P	L /
Economic Incentives	L / S	L / S	L / S	L / S	L / S	H / I	H /
Information	H / P	H / P	H / P	H / P	H / I	H / T	L /

FIGURE U
INFLUENCE OF VARIOUS GROUPS ON IMPLEMENTATION OF NOISE ABATEMENT STRATEGIES

	Airlines	State Aeronautics Comm.	State Legislature	FAA	CAB	HUD	Congress	Other Fed. depts.
I	H/X	L/R	L/R	H/R	L/N	L/T	L/N	L/N
I	H/X	L/R	L/R	L/R	L/N	L/T	L/N	L/N
I	H/X	L/R	L/R	L/R	L/N	L/T	L/N	L/N
S	H/X	L/S	L/R	H/I	L/N	L/T	L/R	H/I
P	M/P	H/P	M/R	H/F	L/N	M/T	L/R	L/N
P	M/P	L/P	L/R	M/P	L/P	L/T	L/R	L/N
F	L/N	L/N	H/R	L/T	L/N	L/T	L/N	L/N
N	L/N	L/N	L/R	L/T	L/N	H/F	L/R	H/F
F	M/F	L/N	M/R	L/T	L/N	H/F	L/R	L/N
N	L/N	L/N	L/R	L/T	L/N	H/F	L/N	L/N
F	M/F	L/N	H/R	L/T	L/N	H/T	L/N	M/T
P	L/N	L/N	L/N	L/T	L/N	H/F	L/R	L/N
F	M/X	L/N	H/R	L/T	L/N	H/F	L/N	L/N
P	H/X	L/N	L/N	L/T	L/N	L/N	L/N	L/N
I	H/X	H/P	L/R	H/R	L/R	L/T	L/R	L/N
P	L/N	L/N	H/R	L/T	L/N	H/F	L/N	L/T
I	H/P	H/R	L/T	H/R	H/R	L/N	L/R	L/N
T	L/T	L/T	L/R	L/T	L/T	L/T	L/N	L/T

upper left:
degree of
involvement
lower right:
type of
involvement

SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 151.

Degree of involvement

H - High or crucial involvement
M - Some involvement
L - Little or no involvement

Type of involvement

R: Initiates regulation or legislation
I: Initiates action
F: Provides funding
T: Technical Advice or service
P: Participate in action
X: May resist strategy
S: Suggest or request change
N: No significant involvement

NOISE ABATEMENT STRATEGIES (top) / NOISE ABATEMENT STRATEGIES (left)	Operational Change	Schedule Restriction	Aircraft Type Restr.	Technological Change	Airport System Change	Airport Design Change	Traffic Demand Change
Operational Change	-/H	+/M	+/M	+/M	-/H	-/H	-/H
Schedule Restriction	+/M	-/H	+/L	+/M	-/H	-/H	-/H
Aircraft Type Restr.	+/L	+/L	+/L	+/L	+/L	+/L	-/M
Technological Change	+/L	+/L	-/M	-/M	+/L	+/L	-/M
Airport System Change	-/M	-/M	-/M	+/M	-/H	-/M	-/H
Airport Design Change	-/H	-/L	-/L	+/M	-/H	-/H	-/M
Traffic Demand Change	-/M	-/M	-/M	-/M	-/M	-/M	/
Encourage Compat. Use	-/H	+/M	+/M	+/H	-/H	-/H	-/H
Public Use	-/H	+/M	+/M	+/H	-/H	-/H	-/H
Relocate Incompat. Use	-/H	+/M	+/M	+/H	-/H	-/H	-/H
Prohibit Incompat. Use	-/H	+/M	+/M	+/H	-/H	-/H	-/H
Sensitivity Changes (Insul.)	-/H	+/M	+/M	+/H	-/H	-/H	-/H
Airport Environs Planning	-/H	-/H	-/H	-/H	-/H	-/H	-/H
Compensation	-/H	+/M	+/M	+/M	-/H	-/H	-/H
Legal Action	-/H	-/H	-/H	-/H	-/H	-/H	-/H
Regulation, Admin.	+/L	+/L	+/L	+/L	+/L	+/L	+/L
Metropolitan Control	+/L	+/L	+/L	+/L	+/L	+/L	+/L
Econ. Incentives	+/L	+/L	+/L	+/L	+/L	+/L	+/L
Information	-/M	-/M	-/M	-/M	-/M	-/M	-/M

Strategy at left is assumed in use. Matrix indicates in
on strategy at left.

FIGURE V
RELATION BETWEEN STRATEGIES

Encourage Compat. Use	Public Use	Relocate Incompat.Use	Prohibit Incompat.Use	Sensitivity Changes	Airport Environs Plg.	Compensation	Legal Action	Regulation, Admin.	Metropolitan Control	Econ. Incentives	Information
+ M	+ M	+ M	+ M	+ M	- M	+ L	- M	- H	- M	- H	- M
+ M	+ M	+ M	+ M	+ M	+ M	+ L	+ L	- H	- M	- H	- M
+ L	+ L	+ L	+ L	+ L	+ L	+ L	+ L	- M	- L	- H	- M
+ L	+ L	+ L	+ L	+ L	+ L	+ L	+ L	- M	- L	- H	- M
+ M	+ M	+ M	+ M	+ M	- M	+ L	- M	- M	- H	- M	- M
+ M	+ M	+ M	+ M	+ M	- M	+ L	- M	- M	- H	- M	- M
+ M	+ M	+ M	+ M	+ M	+ M	+ L	- M	- M	- M	- M	- M
	+ H	+ M	+ M	+ L	+ H	- M	+ L	+ M	- M	+ L	+ M
+ M		+ M	+ M	+ L	+ H	- M	+ L	+ M	- M	+ L	+ M
+ H	+ H		+ H	+ L	+ M	- M	+ L	+ M	+ M	+ L	+ M
+ H	+ H	+ H		+ M	+ M	+ L	+ L	+ M	+ M	+ L	+ M
+ M	+ M	+ H	+ H		+ M	+ M	+ L	+ M	+ M	+ L	+ M
- H	- H	- H	- H	- H		- L	+ L	+ L	+ H	+ L	+ H
+ L	+ M	+ H	+ M	+ M	+ M		+ L	+ L	+ L	+ L	+ M
+ L	+ L	+ L	+ L	+ L	+ L	+ L		+ L	+ L	+ L	+ L
+ L	+ L	+ L	+ L	+ L	+ L	+ L	+ L		+ H	- H	+ M
+ L	+ L	+ L	+ L	+ L	+ L	+ L	+ L	+ L		+ L	+ H
- H	- H	- H	- H	- H	- H	- H	- H	- H	+ L		+ L
- M	- M	- M	- M	- M	- M	- M	- M	+ L	+ L	+ L	

nfluence of application of strategy at top

+ positive:
aids implementation, allows more freedom or no influence

- negative:
restricts implementation, limits effectiveness (may depend on specific instance - indicates strong relationship)

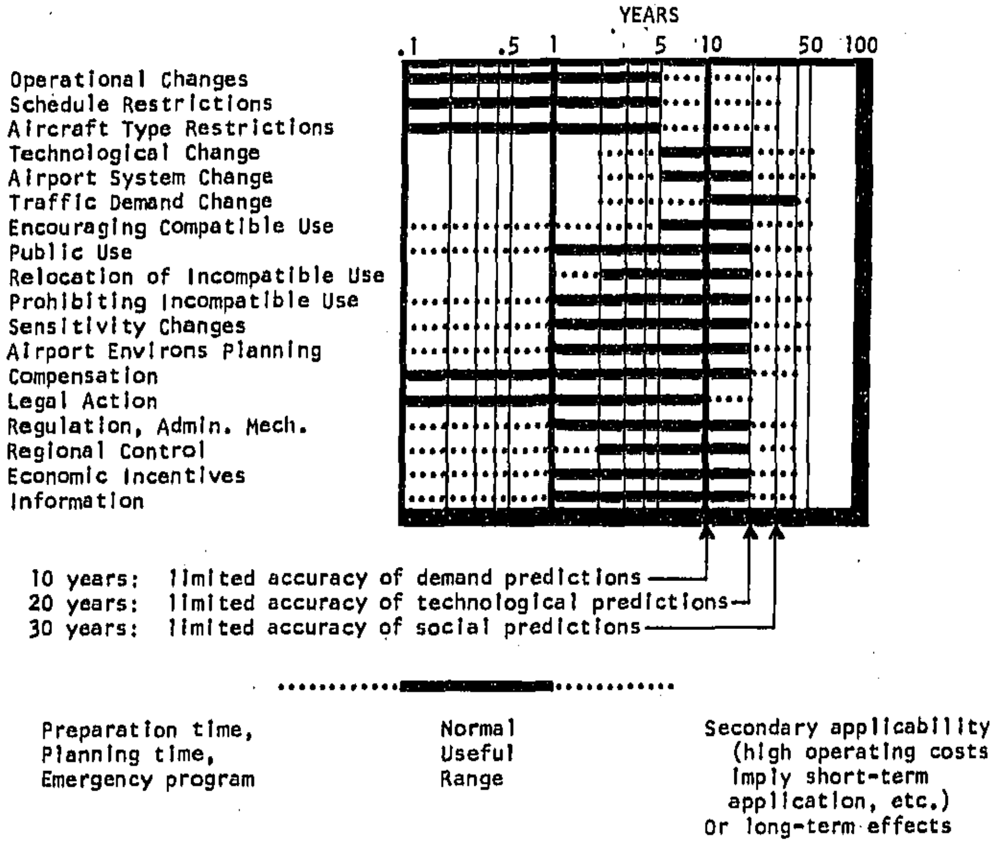
H: close relationship

M: some relationship

L: little relationship

SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 143.

FIGURE W
TIME HORIZONS OF NOISE ABATEMENT STRATEGIES



SOURCE: Aircraft Noise Impact: Planning Guidelines for Local Agencies. U.S. Dept. of H.U.D. Gov't Printing Office, Wash., D.C., November 1972; p. 142.