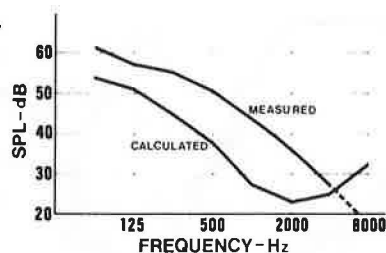


Figure 12. Fan sound level.



possible through the dedicated efforts of the many New Jersey Department of Transportation, FHWA, and Rutgers University personnel involved. Special thanks go to Fred Bogdan and Joe Maiorino, both of Bureau of Surface Design, Area 3, for their input, guidance, and support; to Paul Wygovsky and Robert Lane of the Bureau of Quality Control, for their monitoring data; to Al Ari, resident engineer, construction, and his staff for supervising and coordinating the wall installation; to Lloyd Jacobs, FHWA Environmental Specialist, for his comments; and to Bruce Whitehead, superintendent of plant and equipment, Rutgers University, for his input and coordination with the university. Thanks are also in order to personnel in special engineering, construction practices, and structural design for their input during various phases of the project.

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## Role of Airport Noise Allocations in a Regional Airport System

CHRIS BRITTLE

This paper describes an approach developed in the San Francisco Bay Area to manage aircraft noise at the three major air carrier facilities—San Francisco International Airport, Metropolitan Oakland International Airport, and San Jose Municipal Airport—and to implement policies to develop regional air service. Airport noise allocations, defined by the number of residential dwelling units exposed to noise levels in excess of mandated California state noise standards, represent the noise capacity of each airport. Noise allocations are established at the regional level in a two-step process. First, projected Bay Area air passenger and air cargo demand are assigned to each airport in order to make optimum use of the three regional airports and to expose a minimum of the total Bay Area population to excessive airport noise. Next, noise levels are projected at each airport, with the assumption that aircraft that do not meet federal aircraft noise certification standards are either replaced or retrofitted with quieter engines, and the number of dwelling units in the noise impact area is calculated. Regional noise allocations are designed to accommodate increased aviation demand as well as to encourage airlines to expand their services at Oakland Airport, which is convenient and has the least noise impact of any Bay Area airport. The regional noise allocation is implemented through the power of the individual airports to establish appropriate restrictions on use if annual allocations are not being achieved.

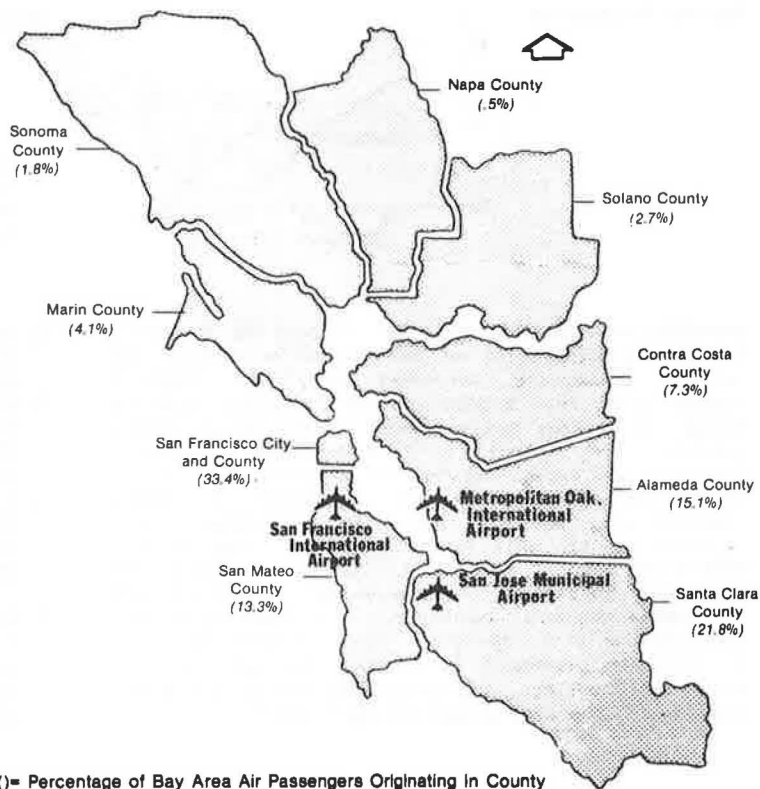
The San Francisco Bay Area is served by three major air carrier facilities: San Francisco International (SFO), Metropolitan Oakland International (OAK), and San Jose Municipal (SJC). Airport noise affects a large number of persons in the Bay Area, hence additional growth in regional aviation demand must be accompanied by a coordinated approach to areawide airport noise problems. Airport system planning

studies conducted by the Association of Bay Area Governments and the Metropolitan Transportation Commission, and funded by the Federal Aviation Administration (FAA), have addressed the noise-control problem and the optimum distribution of traffic among the three air carrier airports to handle future demand.

Two major areas that will provide significant noise relief include a redistribution of airline flights among the Bay Area airports as traffic grows and a reduction in the noise levels of the aircraft. Federal law provides a phased schedule for the retirement of aircraft that do not comply with Federal Aviation Regulation (FAR), part 36, aircraft noise certification standards. Regional studies since 1972 have highlighted the need for greater use of Oakland and San Jose Airports (1,2); however, like other multiairport hubs, most service is concentrated at a single airport—San Francisco International. Since the passage of the Airline Deregulation Act of 1978, service at Oakland and San Jose Airports has declined significantly, due partly to competitive forces and partly to national economic problems.

In spite of the current economic malaise, the long-range outlook is for significant growth in air traffic, which, in turn, will produce increased pressure for effective noise control. The regional noise-allocation strategy is designed to encourage

Figure 1. Location of Bay Area airports and origins of air passengers.



efficient use of the Bay Area airports by the airline industry and to respond to local concerns about airport noise levels. In effect, the noise allocation represents an annual noise capacity or noise budget for each airport, measured in residential dwelling units exposed to noise levels in excess of mandated noise standards for California airports.

Noise allocations are established at the regional level in a two-step process. First, projected Bay Area air passenger and air cargo demand is assigned to each airport in order to make optimum use of the three regional airports and to expose a minimum of the total Bay Area population to excessive noise levels. Next, noise levels are projected at each airport, based on assumptions about the aircraft fleet mix and the noise characteristics of these aircraft. The number of residential dwelling units within the projected airport noise contours can easily be determined and used to define the noise allocations.

Although the noise allocation strategy is discussed in the context of a regional airport system, this approach also provides a useful and practical method for any airport (a) to quantify noise-control objectives, (b) to assess progress by comparing actual noise-monitoring data with annual noise allocations and (c) to define additional noise-control measures necessary to achieve the desired results.

#### REGIONAL ASSIGNMENTS OF AIR TRAFFIC

The relative location of the three Bay Area airports is shown in Figure 1. San Francisco International is the region's major airport facility. It handles 80 percent of the air passengers and 95 percent of the air cargo. Approximately 18 percent of the passengers who use the airport are connecting or through passengers. The airport is located 15 miles south of San Francisco. A large percentage of the aircraft take off over water; however, prevailing

winds from the west cause about 24 percent of the flights to take off over land. These operations impact a densely populated area.

A satellite airport, Oakland International Airport, handles about 9 percent of the air passengers and 1 percent of the air cargo. Service from Oakland International is concentrated in the California corridor between the San Francisco Bay Area and the Los Angeles metropolitan area. Because takeoffs and departures are over water, noise impacts from airport operations are minimal. A major residential development is under construction near the airport, and it will be the only area significantly affected by airport noise in the future.

San Jose Municipal, the Bay Area's other satellite airport, handles 11 percent of the air passengers and 3 percent of the air cargo. Service from this airport is also concentrated in the California corridor. Urban development surrounds the airport; therefore, noise has been a major concern for a number of years. The airport is currently removing homes near the main air carrier runway due to airport noise and safety problems.

Regional planning studies indicate that Bay Area air traffic could increase from 1980 levels of 27 million annual passengers to 37-43 million annual passengers in 1987, and to 45-56 million annual passengers in 1997 (see Figure 2). Recommended air traffic assignments for the Bay Area airports for 1987 and 1997 are shown in Table 1. Regional traffic assignments would result in a substantial redistribution of air traffic, as discussed below.

Air passenger surveys conducted in 1975 and 1980 have shown that the market will support substantially greater service at the Oakland and San Jose airports (3,4). The service areas for these airports each generate approximately 25 percent of the region's air travelers, considerably less than the number currently served. This overall passenger distribution is typical of most city pair markets as

filled with fiberglass (see Figures 9 and 10). Each dormitory enclosure required four silencers as part of the ventilation system.

The barometric dampers are set to open when the plenum pressure exceeds 0.1 in water gauge. This pressure is sufficient to meet the American Society of Heating Refrigeration and Air Conditioning Engineers ventilation requirements for the classrooms. The dampers also provide a constant air flow into the classrooms regardless of the number of open windows.

Also erected at this time were the steel angle supports for the silencers that are mounted against the barometric dampers located in the upper ends of each enclosure. To improve the aesthetics of the completed wall, all these structural elements were painted to match the modular wall panels.

The installation of the wall panels into the steel supports was started as soon as panels were received by the contractor. Because this was a relatively quiet operation and required only a small crane, the university agreed to allow installation of the panels while classes were in session.

A crane was used to lower the panels into place between the support beams. The neoprene strips on the beam flanges and silicone caulk provided a good acoustical seal and prevented rattling of the modular assembly (see Figure 11). Additional fiberglass fill was placed in the channel area where the panels interlock to absorb any sound energy passing through the panel joints before entering the plenum area.

All the panels were placed during April, except in the fan and intake silencer area. At this point, work was stopped because the fan manufacturer could not supply the specified fans due to a back order of the low-vibration motors. The fans specified were direct-drive adjustable vaneaxial and provided a flow rate of 8000 to 14 000 ft<sup>3</sup>/min from 0.25 to 1.5 in water gauge and operating at 1750 revolutions/min. The specification also called for a vibration level not to exceed one mil double amplitude at design-rated speed. These fans caused a substantial delay in completing the project. The fans were received in late May and the installations were completed and operational by July.

The fans were bolted to a concrete pad and isolated with 1-in thick neoprene and cork composite vibration isolation pads. The intake silencers were then set in place and the cover panel was attached over the fans and silencers. The remaining wall panels were then inserted and sealed, which completed the installation.

The bid price for the complete wall installation was \$340 000. Because the classrooms were now protected from construction noise, the university accepted a value engineering proposal submitted by the contractor to substitute driven piles for drilled, cast-in-place caissons to support the cantilevered deck. The minimum cost saving of this construction method is \$210 000. This saving, when applied to the cost of the wall, brings the net cost of the mitigation down to \$130 000, which compares favorably with the estimated cost of \$225 000.

#### TESTING AND VERIFICATION

Several tests have been made to verify the performance of the walls and the accuracy of the predictions. During the spring semester break, when work was proceeding in the canal bed and the structural steel members were being installed on the dormitories, the building noise reduction was measured. The measurements were made by using two B&K 2218 precision integrating sound level meters: one located outside the building 10 ft from the wall and one located inside a classroom 5 ft from the win-

dows. During the measurements a Koering backhoe model 866E was operating approximately 180 ft from the building and generated an  $L_{eq}$  of 70 dB(A) outside the classrooms. The A-weighted noise level was sampled until the  $L_{eq}$  stabilized on both meters. The average measured building noise reduction was 8 dB for open windows and 15 dB for closed windows. These compare with calculated reductions of 7 dB for open windows and 15 dB for closed windows.

After the wall was completed, building noise reduction was measured again. During the measurements, a pile driver (manufacturer and size unknown) drove 20-ft test H-piles. A B&K 2218 was positioned 10 ft outside the completed wall, and a second was in a classroom 5 ft from the windows. The fast meter response was used and the peak noise levels [86 to 94 dB(A)] generated by the driver blows were measured and compared. The results showed a 36 dB reduction with the windows open and a 38 dB reduction with the windows closed. Note that the closed windows condition is only 2 dB better than the open windows condition. There are two explanations for this. First, the noise level within the classrooms due to the mechanical equipment within the building was less than 10 dB below the peak pile driver levels. Second, the pile driver noise levels were noticeably louder in the hallways. Apparently, the noise infiltrated through the building entrances and propagated down the hallways and into the classrooms. The calculated noise reduction with open windows was 38 dB; with closed windows, it was 46 dB. Whether these attenuations are actually achieved cannot be determined because of the complications encountered during the measurements.

The fan noise levels were also measured in the classrooms closest to the fan enclosures. These measurements were made for all six fans by using a B&K 2209 impulse precision sound level meter on fast response and a B&K 1613 octave filter set 5 ft from the open windows. The results showed wide variations between the spectra for each fan--some fans were noisy at low frequencies and others were noisy at the midfrequencies. The average overall level is 52.3 dB(A) with a standard deviation of 2.4 dB (see Figure 12). Unfortunately, we have been unable to determine why such wide variations occurred.

The fan noise levels measured in the six classrooms adjacent to the fan enclosures and outlets result in an NC value of 45 and an SIL of 43 dB. At all the remaining rooms, the design criteria of NC 35 and SIL 35 dB were met due to distance attenuation from the fan.

#### SUMMARY

The major goals for abatement of construction noise have, for the most part, been achieved. The project can be considered successful at this time. To date, all comments received from the university, which cover aesthetics to noise reduction, have been favorable. Up to 8000 students/day are shielded from high levels of construction noise during lecture; therefore, the cost-effectiveness of the wall justifies its inclusion in the project. The added benefits of panel salvage and possible reuse will make the wall even more cost effective.

Whether the need for this type of construction noise mitigation will occur again in New Jersey is not known; however, the experience gained from this project will prove to be invaluable in future construction and traffic noise evaluations.

#### ACKNOWLEDGMENT

Completion of this mitigation proposal was only

Figure 6. Concrete curb for wall.

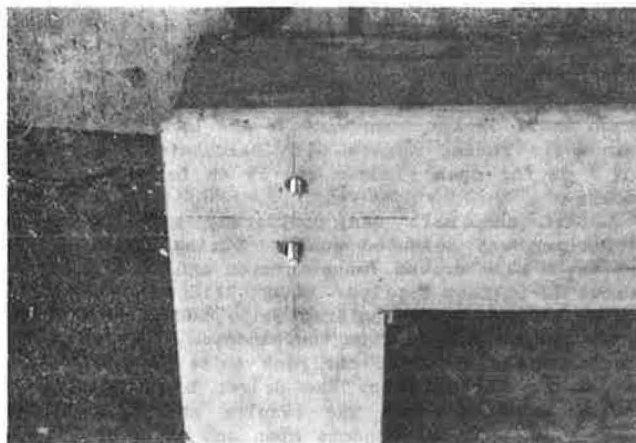


Figure 7. Steel support structure.

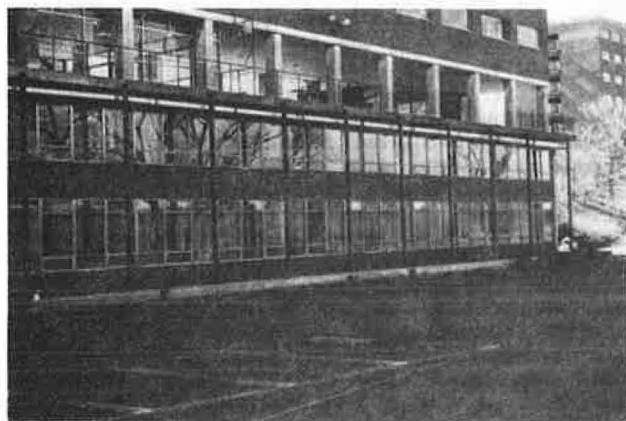


Figure 8. Closeup of support structure, which shows curb, steel H-beam bolted to curb, and 16-gauge U-channel ramset on curb.

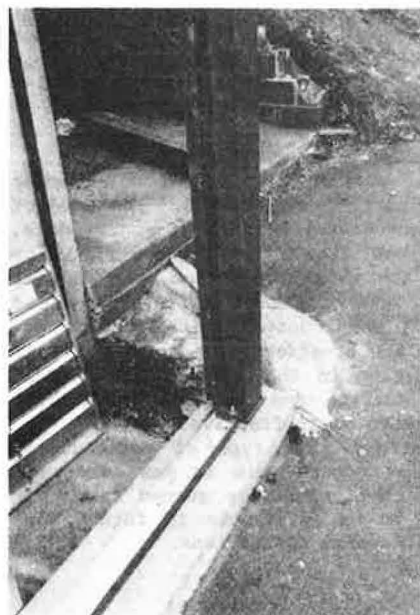


Figure 9. Ten-ft long silencer used on output of ventilation fan.



Figure 10. Completed installation of silencer outlet and steel safe-off panels.

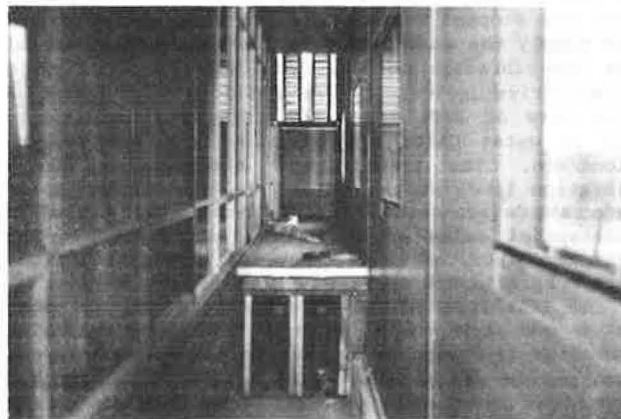


Figure 11. Panel placement.





Figure 2. Air passenger forecast for San Francisco Bay Area.

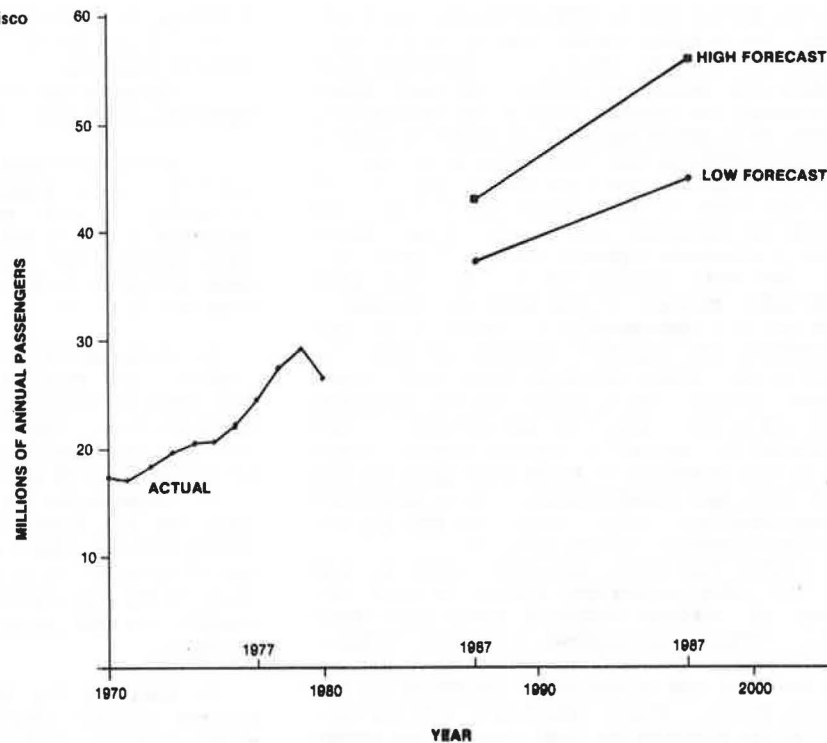


Table 1. High forecast of regional air traffic assignments.

Year	Airport	Air Passengers		Air Freight	
		No. (000s)	Percent	Tons (000s)	Percent
1980	San Francisco	21 338	80.1	318.7	95.4
	Oakland	2 417	9.1	4.7	1.4
	San Jose	2 877	10.8	10.7	3.2
	Total	26 632		334.1	
1987	San Francisco	27 000	63	753.0	90.2
	Oakland	8 000	19	43.0	5.1
	San Jose	7 000	16	36.0	4.3
	North Bay <sup>a</sup>	1 000	2	3.0	0.4
	Total	43 000		835.0	
1997	San Francisco	31 000	55	1524.0	85.4
	Oakland	13 000	23	151.0	8.5
	San Jose	10 000	18	105.0	5.9
	North Bay <sup>a</sup>	2 000	4	5.0	0.2
	Total	56 000		1785.0	

<sup>a</sup>Possible joint use of Travis Air Force Base or a new airport in the North Bay.

well; hence, the larger markets could support expanded service at the satellite airports. In addition, Oakland International's proximity to San Francisco (the origin of 33 percent of the region's airport users) makes this airport a reasonable alternative for air passengers in San Francisco.

Studies of airspace capacity and delay have shown that the airspace system would operate more efficiently if the available capacity at Oakland and San Jose airports is used better. If traffic continues to be concentrated at the San Francisco airport, substantial delays will be experienced in the future during instrument flight rules (IFR) weather conditions (5).

Balancing of the demand among the three regional airports will also balance the demand on the airport ground-access systems and minimize congestion on the regional highways (6). Local and regional air quality effects will be minimized with a redistribution

of airline service (7). Most importantly, the total population in the region exposed to excessive airport noise levels will be minimized by the recommended regional traffic distribution (8).

#### DEVELOPMENT OF AIRPORT NOISE ALLOCATIONS

California has promulgated airport noise standards that govern the level of airport noise in residential areas that surround an airport (California Transportation Title 21, section 5000). Community tolerance to noise is measured in Community Noise Equivalent Levels (CNELs) in dB(A). State law requires that an airport either operate with a zero noise impact area (i.e., no residential units within the applicable CNEL standard) or obtain a variance (other incompatible land uses include schools and hospitals). To obtain a variance, airports must show progress toward meeting the standards and how they intend to achieve compliance. The noise standard becomes more stringent over time, as shown below:

Effective Date	CNEL Standard
January 1, 1976	75
January 1, 1981	70
January 1, 1986	65

The 65 CNEL was used to define the future noise-impact area for each airport because this is the standard with which all airports in California must ultimately comply. Noise levels were projected for each airport to determine the future noise impact area exposed to noise of 65 CNEL or greater. Other noise descriptors, such as the day-night average sound level ( $L_{dn}$ ), can also be used to define the airport noise-impact area.

#### Units of Measurement

The preferred unit of measurement for the regional noise-allocation system is the number of residential

dwelling units within the 65 CNEL contour. In addition to providing a quantitative measure of the community impact of airport noise, the dwelling unit count defines the number of homes that must ultimately be removed, be treated with sound insulation, or be subject to a noise easement in order to comply with the noise standards for California airports.

Since the residential dwelling unit count is used to measure the size of the noise-impact area, one data base can be selected (e.g., U.S. census data) and used for successive updates of the airport impact area. The main purpose of the dwelling unit count is to track changes in the size of the noise-impact area and not necessarily to serve as an accurate inventory of current housing within the noise-impact area. Also, although there will probably be some in-fill construction within existing residential areas that surround an airport, local building standards typically require either sound insulation or the granting of noise easements to the airport for this new construction. As a practical matter, these dwelling units should not add to the potential noise liability of the airport.

Another reason for using dwelling units as the metric for the noise-allocation system is that the effectiveness of various proposed mitigation measures (e.g., airport operational controls, changes in flight procedure, and pricing incentives) can be defined in terms of the anticipated reduction in the dwelling unit count. These reductions can further be broken down by communities that receive the noise relief. Communities need to know how much noise reduction can be provided and whether noise is being reduced or merely shifted from one community to another. Airline decisions may also be affected by the dwelling unit count. For instance, airlines may need to decide whether to accept additional operating constraints at an airport or pay for expanded sound insulation off the airport through landing fees if the stated airport policy is to achieve an equivalent amount of noise reduction.

An alternative unit of measurement to determine the noise-impact area is the number of acres within a noise contour. One problem in using acres is the potential for reducing the size of the noise contour without substantially changing the airport noise impact. This situation would occur if the area of the 65 CNEL contour was reduced over water, over open space, or in an area developed for office and commercial use. The number of acres within the projected noise contour may be useful for defining noise allocations when the density and distribution of residential dwelling units within the noise-impact area of an airport is fairly uniform.

#### Projecting Airport Noise Contours

A predictive noise model was used to estimate future airport noise levels in the Bay Area for two time frames, 1987 and 1997 (8). The principal variables that need to be considered in airport noise modeling are as follows:

1. Air traffic demand--the overall demand projections and distribution of traffic among the three air carrier airports,
2. Airline fleet mix--the projected airline fleet mix associated with each airport traffic level and the noise characteristics of this fleet mix,
3. The distribution of aircraft operations by time of day--the CNEL standard weights aircraft noise emissions more heavily between 7:00 and 10:00 p.m. and between 10:00 p.m. and 7:00 a.m. to reflect lower community tolerance for noise in the evening and late night,
4. Flight procedures--engine thrust and flap

settings for individual aircraft types,

5. Flight track use--airport arrival and departure routes, and

6. Airport operational controls--restrictions on noisy aircraft and curfews.

Of major interest from a regional planning perspective is the population in the region exposed to excessive airport noise, given different traffic assignments among the Bay Area airports. To address this question two major airport system alternatives were compared based on the future forecast of Bay Area air traffic.

1. Alternative 1: Existing airport traffic shares. The traffic distribution among the three Bay Area airports duplicates the existing traffic distribution. San Francisco International would continue to handle close to 80 percent of all air passengers and 95 percent of all air cargo.

2. Alternative 3: Regional airport plan. Oakland and San Jose airports would serve a significantly greater share of regional demand and a North Bay airport would provide limited air carrier service in the California corridor (noise impacts associated with the proposed North Bay Airport would be minimal).

In addition to the proposed redistribution of airline flights among Bay Area airports, another major airport noise-mitigation measure incorporated in the regional noise allocation was the phase out of all older, noisier aircraft currently in operation. It was assumed that all aircraft would comply with FAR Part 36 aircraft noise certification standards by 1987. Current federal statutes require aircraft that do not meet FAR Part 36 to either be replaced or retrofitted with new technology engines by 1987. New technology aircraft (e.g., B737-300, B757, B767, and DC-9-80) are generally assumed to meet the more-stringent stage 3 noise levels and estimates were made of the noise characteristics of these aircraft.

In order to clearly identify changes in regional noise impacts due to alternative airport traffic distributions and aircraft technology, other variables were held constant. For instance, it was assumed that airlines would continue to schedule flights at the preferred arrival and departure times for passengers and cargo and that current aircraft operational procedures and airport flight track use would not change in the future. As a matter of policy it was also assumed that any decisions regarding curfews, maximum aircraft noise limits, changes in flight procedures, and economic incentives to reduce noise would be the responsibility of the airports and federal agencies and would not be incorporated in the regional noise allocation. This assumption is based on the fact that regional strategy incorporates noise reduction at the source--the aircraft--as the major mitigation measure while leaving the door open to the airports and communities to implement other measures if the regional noise allocations are not achieved or if further noise reduction is desired.

#### Counting Dwelling Units Within the 65 CNEL Noise-Impact Boundary

Determination of the population and number of dwelling units within an actual or projected noise contour can be a fairly time-consuming process unless modern computer techniques are employed. This process has been completely computerized in the Bay Area through the use of the Bay Area spatial information system (BASIS) program developed by the Asso-

ciation of Bay Area Governments (9). In brief, BASIS is structured around an array of grid cells, each of which represents a land area of 1 hectare (100 m<sup>2</sup> in the Universal Transverse Mercator coordinate system or about 2.5 acres). Each cell on the ground corresponds to a unit of computer storage. The unit contains data codes that represent the characteristics of that cell. Data of importance to airport noise assessment include census data, dwelling units and population, school sites, hospital sites, and noise levels. Noise contours are entered into the computer via a digitizer that quickly translates mapped data into the cell for-

mat. Once the information is entered, BASIS can overlay one data set (e.g., noise levels) on another (e.g., dwelling unit) and produce a quick analysis of the effects of changing noise contours on residential areas.

#### Recommended Noise Allocations for Each Airport

Figures 3 and 4 show how the population exposed to noise levels of 65 CNEL or greater varies at each airport as a function of the number of aircraft operations and projected aircraft fleet mix for 1987 and 1997. Estimated differences in regional airport

Figure 3. High forecast of noise impacts versus annual jet air carrier operations in 1987.

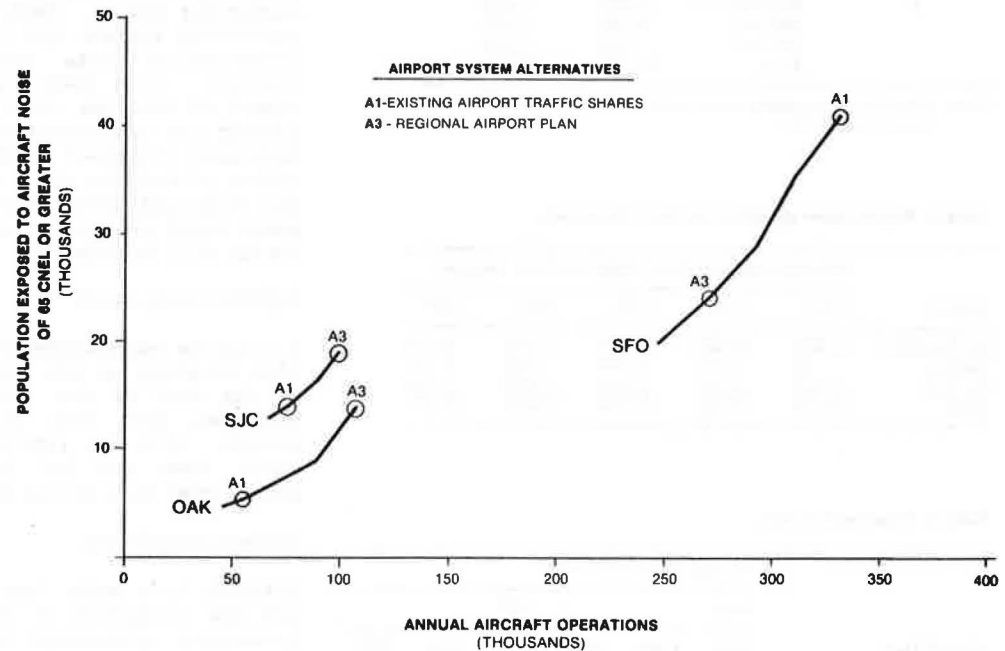
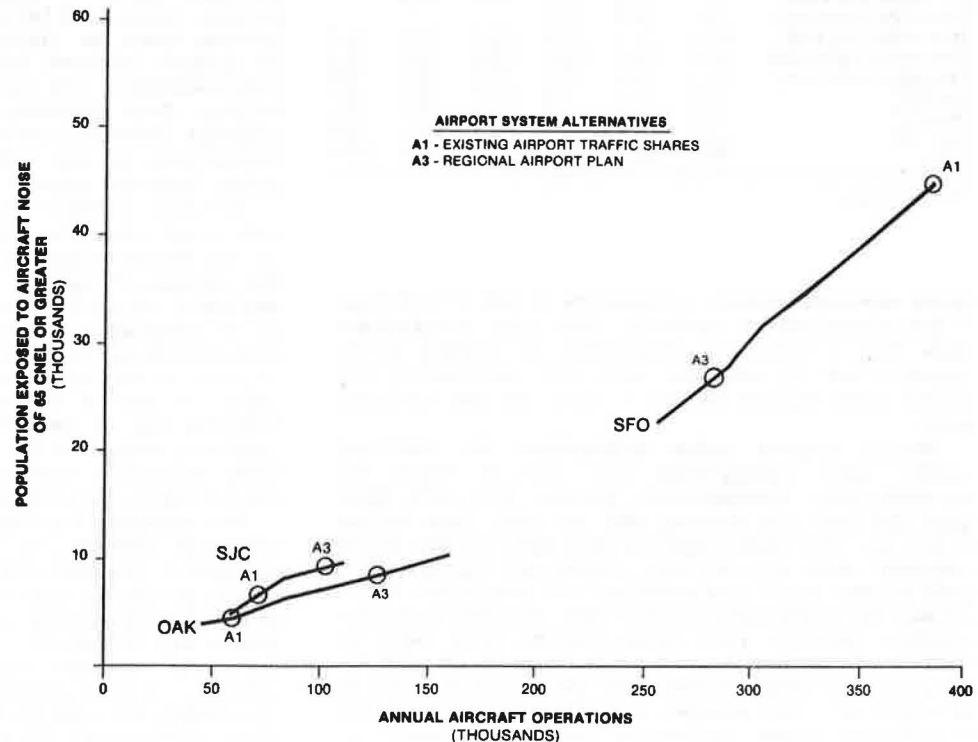


Figure 4. High forecast of noise impacts versus annual jet air carrier operations—1997.



**Table 2. Population and dwelling units exposed to airport noise levels of 65 CNEL or greater.**

Year	Alternative	Airport	Population	Dwelling Units
1987	1	San Francisco	41 460	14 530
		Oakland	5 530	2 130
		San Jose	14 410	4 850
		Total	61 400	21 510
	3	San Francisco	23 560	8 630
		Oakland	13 720	5 340
		San Jose	18 660	6 400
		Total	55 940	20 370
1997	1	San Francisco	45 440	15 640
		Oakland	4 450	1 730
		San Jose	6 730	2 060
		Total	56 620	19 430
	3	San Francisco	27 090	9 610
		Oakland	8 740	3 320
		San Jose	9 350	2 990
		Total	45 180	15 920

Notes: Alternative 1 is the existing airport traffic shares. Alternative 3 is a regional airport plan.

**Table 3. Regional noise allocation for Bay Area airports.**

Airport	Projected Dwelling Units Within 65 CNEL Contour				
	1976	1981	1986	1987	1997
San Francisco	12 400	10 690	8 970	8 630	8 630
Oakland	80	1 730	3 390	3 720	3 320
San Jose	1 630	3 800	5 970	6 400	2 990
Total	14 110	16 220	18 370	18 750	15 920

**Table 4. Projected fleet mix.**

Aircraft Type	Average Daily Operations					
	1987			1997		
	SFO	OAK	SJC	SFO	OAK	SJC
Four-engine wide body	73.9	1.2		93.0	23.6	
Four-engine regular body	94.6	26.1	18.6			
Three-engine wide body	109.3	22.3	10.5	126.4	51.8	43.2
Three-engine regular body	281.5	165.4	154.6	180.0	91.0	91.2
Two-engine regular body	118.2	52.6	66.4	59.8	40.6	30.2
New 200 <sup>a</sup>	40.6	12.1	8.0	132.4	50.8	48.7
New 150 <sup>a</sup>	15.6	0.5	6.2	79.3	34.1	32.6
New 125 <sup>a</sup>	9.3	5.2	3.5	101.4	54.7	34.0
Total	743.0	285.4	267.8	772.3	346.6	280.0

<sup>a</sup> New technology.

noise exposure between alternative 1 and alternative 3 are summarized in Table 2. The noise projections show that substantial reductions in airport noise exposure can be achieved with the recommended regional distribution of air traffic in the regional plan.

Annual airport noise allocations (in dwelling units) were established for interim years by straight-line interpolation between the 1976 base year and 1987 and between 1987 and 1997 (see Tables 3 and 4). Two modifications were made in the final regional noise allocations. First, one Oakland Airport flight track was modified and overflight noise caused by eastbound traffic was reduced significantly. Second, 1997 noise impacts were held to 1987 levels at San Francisco Airport. These modifications were incorporated into the regional plan as a result of local studies that showed potential for significant noise mitigation based on changes in

flight procedures, flight track use, and aircraft noise restrictions (10).

There has been discussion concerning the validity of a linear interpolation procedure since such a procedure does not consider the timing of individual airline aircraft delivery programs or major federal aircraft compliance dates for replacement or retrofit of non-Part 36 aircraft. The precise effect of airline aircraft acquisition programs on a specific airport would be difficult to determine; however, and the straight-line approach is reasonable public policy.

### Monitoring Progress

Each Bay Area airport is equipped with a noise-monitoring system. Data recorded from these noise-monitoring systems can be used to prepare airport noise-contour maps either annually or semi-annually. Once these contours are developed, the number of dwelling units within the actual 65 CNEL contour can be counted (by using the computer-based technique discussed above) and compared with the number of dwelling units targeted for the airport in the noise-allocation process. If the actual measured count exceeds the desired count, further mitigation will be required.

### INSTITUTIONAL ROLES

A complete explanation of the regional noise-allocation strategy is not possible without a discussion of the role of the various actors. A number of questions have been raised concerning this approach: Will the regional noise allocation really work? Have the Bay Area airports adopted this plan? What will be the impact on the airlines?

### Airport Proprietor

Although this paper focuses on California airports and the regulation of noise through administrative procedures established by California, all airports throughout the country are potentially liable for personal injury or property damage resulting from airport noise. Noise-control programs are an important means for limiting airport liability and are of general interest for this reason. Airports can take reasonable and fair actions to limit their liability. This authority provides the backbone of the regional noise-allocation strategy. Regional noise allocations do not tell an airport how to reduce noise, just the overall objective.

Although a number of airports have projected future noise contours, they have not used the contours in the manner suggested in this paper; that is, for the purpose of setting specific, quantifiable noise-abatement objectives over a period of years. One major advantage to the airports is that the noise allocations can be related to noise monitoring data so that a continuous report on progress is available. A second advantage is that a variety of measures can be considered to meet the annual objectives, depending on local conditions. A significant, intangible benefit is that community relations can be vastly improved by having such a program.

The regional approach addresses cumulative noise exposure; however, a comprehensive airport noise-mitigation program needs to consider other irritating problems, such as noise in the late evening and extremely noisy aircraft whose single event levels are disruptive to residents who live in the area and to teachers and students in nearby schools. A more-comprehensive set of noise-control strategies may also be necessary if the noise reductions anticipated through the airlines' fleet re-



equipment program do not materialize. One measure available to the airport operator for controlling noise is the use of standardized aircraft noise-emission data to exclude the noisiest aircraft from an airport. A variation of this control measure--elimination of noisy aircraft from the late evening--will have a dramatic effect on the size of the noise contour and will offer a real measure of relief to persons who live around airports.

At the time of this writing, San Francisco International formally adopted a noise-mitigation program and a series of yearly noise budgets (11). San Jose Municipal has suggested a lower allocation for its airport due to community pressure to reduce airport noise levels. Since the noise allocation for San Jose airport may be reduced, the noise allocation for Oakland International would have to be increased to provide an equivalent noise capacity for the region. This possibility was anticipated in adopting a stepwise approach to establishing noise allocations for each airport. By starting with the airports that have the greatest noise problem (San Francisco and San Jose) and leaving the final adjustments for the airport with the least noise problem (Oakland), the total noise capacity of the region can be preserved.

Some legal protection from liability for noise damages might also be considered to provide both airlines and airports with incentives for accomplishing the noise-allocation program.

#### Communities

The regional noise-allocation strategy primarily addresses the airport side of the noise problem by concentrating on the amount of noise that will be generated at each airport and how this noise can be controlled. Most communities in the Bay Area now understand that noise levels may be reduced but airport noise will not disappear and airports may not get appreciably quieter. The regional noise-allocation strategy helps communities understand the role of each airport in the regional airport system and the magnitude of the residual noise impacts once airlines have retired their noisier aircraft. Implicit in the regional noise allocation is a sharing of responsibility for noise problems between the community and the airport. Once the airport has agreed to do its fair share in reducing noise, local communities need to help plan methods for preventing new incompatible land uses and for correcting existing incompatible land uses. Correction of existing incompatible land uses is a lengthy process and can take several forms: removal of homes, sound insulation, voluntary relocation assistance, or purchase of noise easements. Regional agencies have encouraged the airports and communities to jointly prepare a program for continuing remedial action in the airport noise-impact area. Legislative changes may be necessary to mandate more-effective land use planning in the airport environs.

Bay Area communities like the regional noise-allocation concept because it is easily understood and because the progress of the airports in controlling noise can be monitored through the preparation of periodic noise-contour maps. Communities have become involved in the establishment of the noise allocations (a) to ensure that all reasonable operational controls are evaluated by the airports and (b) to protect their interests if it appears that noise will be shifted from one community to another.

A recent joint study that involves the San Francisco airport (which is located in San Mateo County) and the cities in San Mateo County resulted in a

noise-allocation program that exceeds the regional objective (11).

#### Airlines

Airlines that serve the Bay Area have a major investment in airport facilities and their aircraft fleets. The regional noise allocation provides sufficient noise capacity for new carriers to enter the Bay Area, for existing carriers to expand service, and for carriers to continue to operate during most hours of the day--provided the airlines continue to invest in new, quieter aircraft. Due to national economic problems and the current slowdown in air travel, noise levels at all Bay Area airports are significantly below their annual allocations. At San Francisco airport, for instance, the number of dwelling units in the 65 CNEL contour is 40 percent lower in 1981 compared with 1980.

As traffic increases in the future, the noise allocation will come into play at various times at each airport. The airlines could continue to concentrate service at San Francisco airport by collectively agreeing to undertake more-extensive forms of noise mitigation. If San Francisco airport is unsuccessful in negotiating additional mitigation measures with the airlines, unilateral actions could be considered to reduce airport noise levels to the yearly allocation. For example, one action might be to prohibit noisier aircraft (based on manufacturer certification data) from using the airport. Carriers that have such aircraft could use them at other Bay Area airports, provided those airports had not exceeded their own noise budgets.

#### Federal Agencies

Based on past experience, FAA and Civil Aeronautics Board (CAB) have expressed concern when an airport's noise restriction policy (a) placed a significant burden on interstate commerce, (b) was unreasonable, (c) discriminated against a particular carrier or group of carriers, or (d) preempted federal authority. The regional airport noise-allocation strategy avoids all of these concerns. In particular, the regional noise-allocation strategy deals directly with the noise issue and avoids limiting access to Bay Area airports by new or incumbent carriers for arbitrary reasons.

#### Regional Agencies

The success of the regional noise-allocation strategy in achieving regional air service objectives depends on the persuasive power of the regional agencies to convince the Bay Area airports to adopt a coordinated set of noise budgets. The trend in current noise control debates at most airports is to seek reductions in airport noise below current levels. The regional noise-allocation strategy, therefore, involves a difficult and politically sensitive process of building consensus for increased noise at some airports (Oakland and San Jose) while noise is reduced at San Francisco airport.

Regional interest in having the individual airports adopt the noise budget concept as a noise management tool is strong. Regional agencies may become involved in the granting of variances to the Bay Area airports. The noise variance process in California provides for public hearings on whether or not a variance should be granted to an airport that is not in compliance with the airport noise standards. A further part of the variance process is to determine what conditions, if any, should be attached to the variance. Regional agencies will vigorously support the granting of a variance when

an airport demonstrates that it is achieving its noise-allocation objectives. Alternatively, the regional agencies will argue for more-stringent conditions to be included in the variance if sufficient progress is not being achieved.

#### CONCLUSION

This paper has outlined the major elements of a regional noise-allocation program that provides an areawide approach to development of airline service and airport noise control. Future experience will determine the success of this concept. The methodology is straightforward and requires only the monitoring of noise levels on an annual or semi-annual basis and a comparison of actual noise impacts with the annual noise allocations. The approach relies on the proprietary powers of the three Bay Area airports to achieve the desired results. It is easily understood by local communities and provides considerable flexibility to the airports in determining how to meet the annual objectives. In addition, this approach has significant merit as a noise-management tool—not just for a regional system of airports, such as the Bay Area, but for individual airports in other parts of the country as well.

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## Comparison of Irritation Caused by Noise Generated by Road Traffic and Aviation Traffic

WERNER BRÖG, GÜNTHER-FRITZ HÄBERLE, AND BARBARA METTLER-MEIBOM

Acoustic measurement methods are necessary in order to measure noise objectively. On the other hand, the use of decibel values to determine the degree to which persons subjectively perceive noise to be disturbing is a distortion because no acoustic measurement methods can objectively reflect how persons perceive noise. In light of this, one is justified in wondering whether dB(A) measurement can possibly account for the level of discomfort that intervals of quiet or noise cause to humans. The answer can be found if one compares the effects that two sources of noise that have the same dB(A) but different intervals of quiet between the noise have on persons exposed to the noise. In this paper, two different sources are discussed—noise generated by road traffic (which is continuous noise) and noise generated by aviation traffic (which is noise interspersed with longer or shorter periods of quiet). For our study a sample group of persons was first exposed to noise caused by aircraft traffic and then to noise caused by road traffic; the dB(A) for both was the same. The test persons then filled out questionnaires that dealt with their reactions to these different sources of noise. A laboratory situation was deliberately avoided, since this can never be comparable to the actual conditions found in real-life situations and, thus, necessarily results in errors. The hypothesis of the study—that the same dB(A) can be very differently perceived by persons when the source of the noise is different—was clearly proven to be true. Not only were

a greater number of persons irritated by noise from road traffic than by aircraft noise, but the perceived degree of disturbance was also more intense. The study discussed here was a pretest that used a sample of only 107 persons and could not take into consideration the long-term effect of their past experiences with noise.

A whole spectrum of social scientific and acoustic studies explain and analyze specific aspects of the problem of noise as an environmental pollutant. These studies usually deal with the irritation to persons who are exposed to noise daily or, at least, regularly. Thus, noise is directly dealt with; that is, persons who have been exposed to noise over a long period of time are studied, and the sample group usually knows that its reactions to noise are being tested. The present study, sponsored by the German Federal Office of Environment (1) was structured so that test persons would be exposed to noise