Efficiency, Economic Incentives and Noise Treatment Policy: The Ben-Gurion Airport Experience

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Aircraft noise is the most prominent negative externality of airports. It has been the main source of community opposition to airport development plans. The current approach to airport noise mitigation emphasizes long-term compatibility. It is based on standards for aircraft noise emissions and the promulgation of airport noise compatibility plans. Such plans are based on computer-generated forecasted noise exposure maps. The validity of noise maps is a function of the validity of the inputs used to generate them. A review of these inputs reveals that their forecasts are subject to inherent uncertainty. Although noise maps reflect current noise conditions accurately, maps depicting noise forecasts are inherently uncertain. Allocating funds for mitigation based solely on such forecasts may thus be inefficient. This paper suggests that relating mitigation expenditures to current noise levels is more efficient. Relating airports' outlays on noise mitigation to the noise effects of their operations provides airports with an economic incentive to operate in a noise-sensitive manner. It may shift the focus of public debate from the assumptions underlying noise forecasts to the criteria for noise abatement, a shift that arguably may help reduce opposition to airport development plans. A number of implementation issues are discussed and the approaches used to deal with these issues in Ben-Gurion Airport are described.

Aircraft noise is the most prominent negative externality of airports. It has been at the center of community opposition to airport development plans throughout the world. Most large airports have noise problems (*1*).

The current approach to aircraft noise mitigation emphasizes long-term compatibility between airports and their surroundings. It is based on reducing noise at the source (aircraft) using emission standards and on the promulgation of airport noise compatibility plans. Such plans are based on noise forecasts. Yet, as this study shows, such forecasts are subject to inherent uncertainties. Consequently, noise mitigation measures based on such forecasts may be inefficient. This paper argues that this pitfall may be overcome by modifying compatibility plans to include a mitigation program based on current noise levels and backed by a monitoring system. Such a program would also provide the airport with an equitable economic incentive for noise-sensitive operations.

The present approach and its limitations are briefly reviewed in the first section. Economic incentives have often been mentioned as alternative or complementary methods for aircraft noise mitigation (*2*). They have been increasingly used in Europe and Japan (*3,4*), but not in the United States (*5,6*). The next section reviews the possible uses of economic instruments for airport noise mitigation. Most studies and applications of noise-related charges focus on the airlines. In the third section, a simple airport-oriented approach to noise mitigation is suggested. This approach is shown to provide an economic incentive for airports to operate in a noise-sensitive manner. Some implementation issues related to this approach are also discussed. The fourth section suggests ways to address the implementation issues. It focuses on the example of Ben-Gurion airport in Israel, where such an approach has recently been adopted.

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CURRENT APPROACH AND ITS LIMITATIONS

The ability to achieve long-term compatibility between airports and their environment is a function of two factors: (a) the ability to reduce noise at the source to offset the growth in volume of operations; and (b) the ability to reduce current population exposure to noise and to prevent population growth in affected areas through operational procedures, zoning, noise insulation, and purchase of land, houses or development rights.

The policies to reduce noise at the source have been based on setting standards that all aircraft would have to meet at specified dates. In the United States, these standards were set in Federal Aviation Regulations (FAR) Part 36; in Europe and the rest of the world they are usually based on International Civil Aviation Organization (ICAO) Annex 16. Toward the end of the 1970s, stricter standards were adopted for third-generation aircraft (FAR 36 Chapter 3, ICAO Annex 16 Chapter 2). The technological limits to source noise reduction have probably been reached with third-generation aircraft. The turnover from stage two to stage three aircraft has been slower than anticipated. Reduction of noise at the source thus has long-term limitations on the extent to which it can offset the additional noise that results from the increasing volume of flights.

To complement the source reduction policy, most countries have suggested and implemented policies to reduce the exposure of population in areas around airports. In the United States, such policies have been suggested in FAR Part 150. The basis for any noise compatibility plan under FAR 150 is a noise exposure map forecasting the noise contours around the airport 5 years in the future. The cost-effectiveness of some measures suggested in FAR 150, such as zoning, insulation, and acquisition of land, development rights or houses in high-exposure areas, depend on the accuracy of the noise exposure map.

Noise maps are generated by computer models. The best known model is the Integrated Noise Model (INM). All models, however, follow the same basic procedure; that is, they require similar inputs and produce similar outputs. The inputs generally required are the number of operations by aircraft type, day or night, for each flight track/runway combination. These inputs, in turn, depend on the following variables:

- Number of daily operations
- Breakdown between day and night operations
- Types of aircraft used
- Runway use patterns
- Takeoff and landing procedures
- Flight tracks
- Flight track usage (a function of the runway used and flight destination)
- Relative weight of aircraft taking off, usually expressed as stage length

The INM model is usually considered accurate. The results, however, are sensitive to changes in inputs (*7*). The accuracy and validity of the noise contours generated by the model are therefore primarily a function of the accuracy and validity of the inputs. If the number of operations or the day/night breakdown of operations is inaccurate, the overall area exposed to noise (above any specified level) would be affected. If runway use pattern, flight tracks or flight track use patterns are misspecified, the noise distribution around the airport will be different from that forecasted. If aircraft types, takeoff and landing procedures, or stage lengths are inaccurate, both the shape of noise contours and the total area covered by them would change. If all the inputs are accurate, noise models generally correspond well to monitored noise. Although the current values of all inputs are usually known, forecasts of most inputs are highly uncertain.

The aforementioned variables can be divided into two groups. The number of daily operations, day/night breakdown, types of aircraft used and destinations (which affect flight track usage and stage length) are primarily a function of decisions made by airlines. These decisions are, in turn, a function of changing local, national, and international market conditions that are subject to great uncertainty (*8*). With the advent of hub-and-spoke operations and the consolidation of the airline industry through mergers, concentration ratios in many hubs increased significantly. That is, a smaller number of airlines are responsible for a larger percentage of the operations. Consequently, the values of these variables are often highly dependent on the routing decisions of a very small number of airlines. It is practically impossible to forecast such routing decisions beyond the immediate future.

Furthermore, in multiple-airport regions the choice of airport by passengers is highly influenced by the availability of direct flights, and is thus also a function of airline routing decisions (*9*). In such regions, the demand for airport services is also a function of actions undertaken by airlines and competing airports in the region, increasing the uncertainty regarding any forecasts of operations in the airport (*10*).

Runway use patterns, flight tracks, and takeoff and landing procedures are decisions airports can influence (*6*). In practice both runway use patterns and flight tracks may change quite often, because they are a function of a host of considerations including the weather, safety, airline demands, and infrastructure limitations. In the Baltimore/Washington International Airport (BWI), for example, 1985 runway use patterns used to forecast noise in the new master plan were obsolete by 1987 (*10*). Consequently, even though these decisions can be affected by the airport, substantial uncertainty exists regarding the values of such variables in the future.

As a result of all these uncertainties, actual noise contours often deviate significantly from forecasted levels. This can be seen in Figure 1, which depicts the 1982 noise zone and 1987 actual 65 Ldn contours of BWI, a typical medium hub (*1*), whose noise forecasts have usually been state of the art (*11,12*). Figure 2 shows the implications of the deviation between forecasts and reality in terms of land area, housing units, and population exposed. In relating the two figures, it is important to note that there were deviations not only in total exposure between forecasts and reality but also in the spatial distribution of housing units affected. Thus, although in some areas the noise levels were higher than forecasted, in others they were lower.

Noise mitigation efforts based on forecasted noise may thus be somewhat misdirected, and consequently inefficient; that is, expenditures may be undertaken on the basis of projected noise levels at sites that ultimately would not be exposed to such levels. At the same time, other untreated sites may be exposed to higher noise levels, ultimately requiring additional expenditures.

ECONOMIC INCENTIVES FOR NOISE MITIGATION

The shortcomings and limitations of the current approach have led several countries to consider the use of various noise-related charges to induce a faster turnover to quieter aircraft, to ensure compliance with noise mitigation procedures and to finance mitigation efforts such as insulation and purchase of houses in noise-stricken areas (*3*). Most noise-related charges discussed and implemented are targeted at airlines. Economic theory suggests that, if set properly, such charges would lead polluters (airlines) to reduce emissions (noise) to the desired level in a cost-effective manner (*2,13*). Setting the charges specified by economic theory, however, would require at least identifying marginal damage functions. Estimates of such functions have often been questioned on both theoretical and empirical grounds (*14*). Alexandre et al. (*14*), having surveyed the various approaches to setting noise charges and the difficulties in implementing them, suggest that a third best approach to set them would be as a function of noise abatement costs in forecasted noise zones, and aircraft types expected to be used during the forecast period. Yet, as discussed in the previous section, both these inputs are uncertain, and thus noise charges set in this manner may also be misspecified.

Economic incentives, however, can also target airports. Currently, airports in the United States have two economic incentives for noise mitigation: litigation by nearby property owners, and federal subsidies for implementing noise compatibility plans.

Litigation is costly. Because communities differ in terms of resources and organization, some communities may be able to litigate more (and better) than others. This gives airports an incentive to avoid the more litigious communities, which may come at the expense of less organized ones. Federal

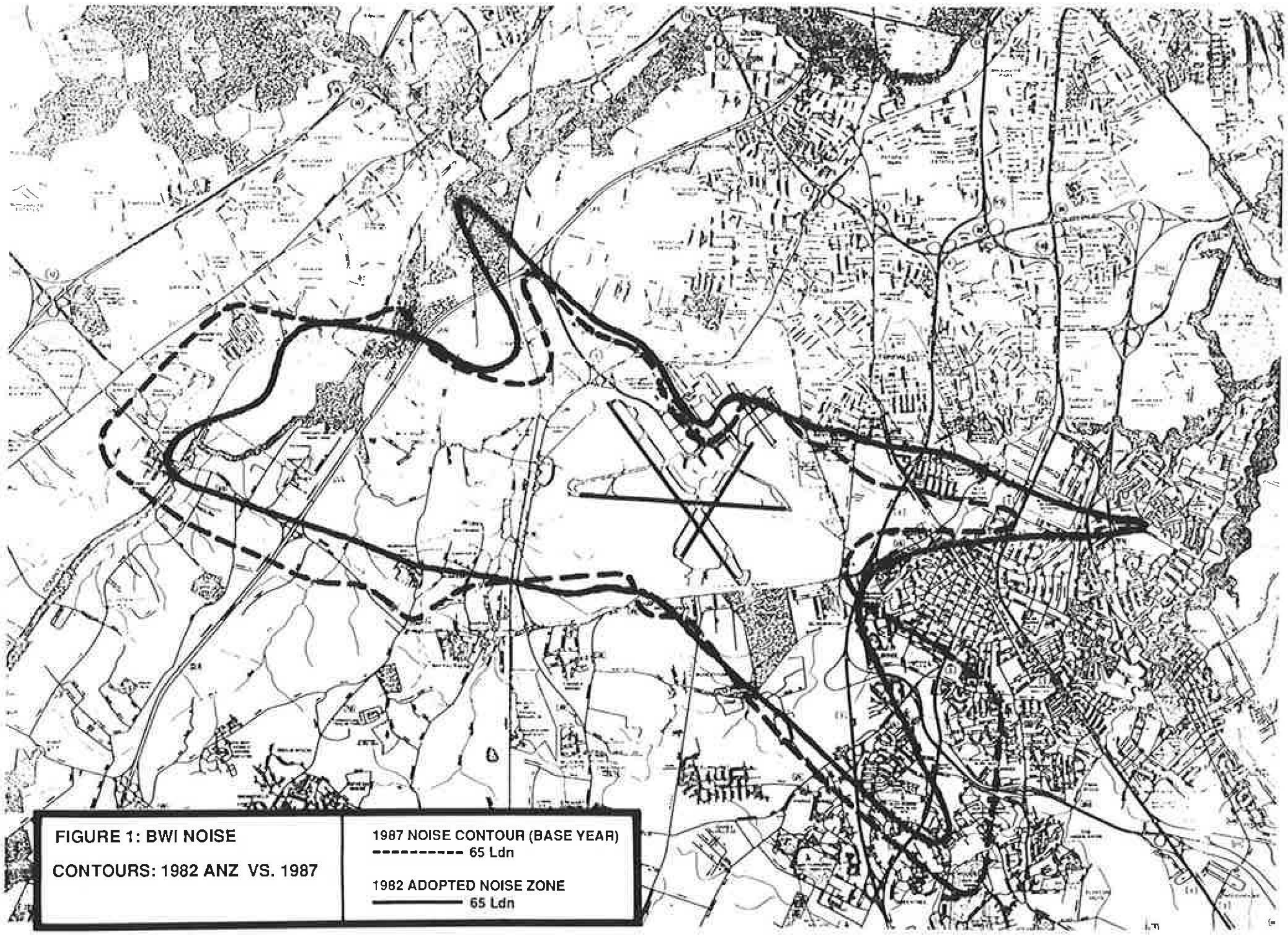

FIGURE 1 BWI noise.

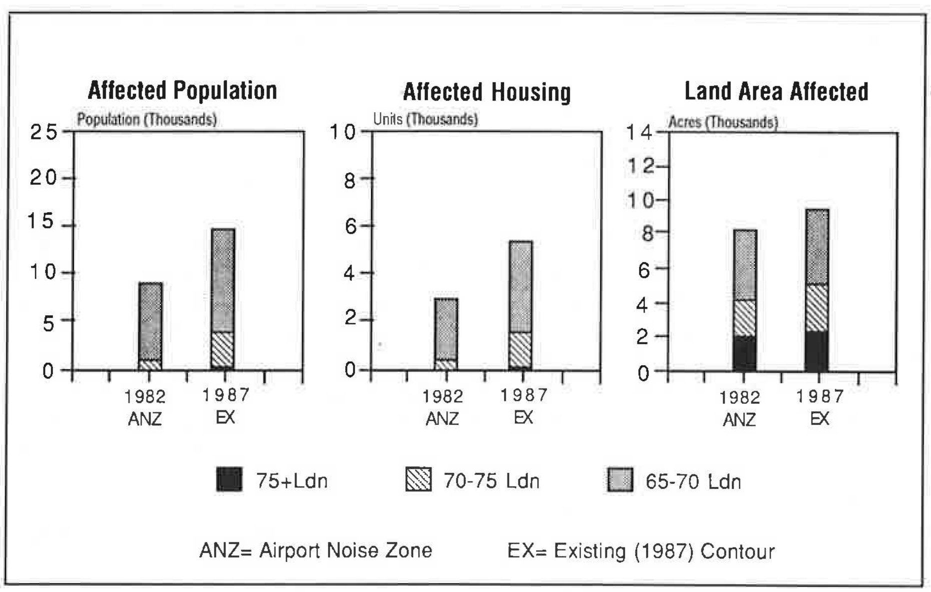

FIGURE 2 BWI noise effects: 1982 forecast vs. 1987.

subsidies are provided for noise compatibility planning and for implementing noise mitigation measures suggested in such plans. Yet, if such measures are based on uncertain noise forecasts, they may be inefficient because they may not be implemented in some areas exposed to high noise levels, while federal funds are used in areas that ultimately will be subjected to lower noise levels.

NOISE TREATMENT AS AN ECONOMIC INCENTIVE

The dependency on noise exposure maps can be avoided by requiring that noise mitigation measures at the receptors be undertaken on the basis of current, rather than forecasted noise levels. Current noise levels can be determined by running a model with current inputs, calibrated and validated by a (limited) monitoring system. Such an approach should not be too difficult to implement because many major airports already have noise units and operate monitoring systems, for calibrating noise forecast models, for evaluating citizen complaints, and for monitoring aircraft compliance with noise-mitigation procedures (*15*). Furthermore, FAR 150 requires the preparation of current noise maps, in addition to 5-year forecasts, as part of the material to be submitted, and the updating of noise maps when significant increases in noise exposure occur.

The noise monitoring system would be used to validate the accuracy of the current model-generated noise map, calibrate the model for local peculiarities (such as terrain), and verify the validity of the inputs (especially pertaining to aircraft behavior). The current, monitor-validated noise map could then be used to evaluate whether any specific area is subject to noise exposure above a prespecified level, entitling it to receive funds in the form of noise insulation, purchase price assurances, moving compensation, or any other combination or form of compensation for the granting of navigation easements. It should be noted that this approach does not preclude the use of noise forecasts as a basis for evaluating airport improvement projects, zoning or purchase of land and development rights. Rather, it is meant to complement the other elements by providing a cost-effective way to deal with the noise problems of existing sensitive land uses.

An important facet of this proposal is its creation of a connection between airport operations and their noise-related expenditures. Measures to reduce flights in a certain area would be reflected in the current noise map for the airport and translated into a reduction in receiver-oriented mitigation costs (such as insulation). If an airport relaxes some of its operation requirements (such as noise abatement flight tracks, landing and takeoff profiles, or slot or capacity limitations), it would face an increase in receiver-oriented mitigation costs. This proposal thus provides the airport with an incentive for operating in a manner that would minimize noise exposure. In a sense it is similar to the incentive provided by litigation, but it is based on costs of noise mitigation (which are a function of exposure) rather than on the costs of litigation.

Relating noise mitigation to current noise may also improve the relationship between airports and their surrounding communities. When noise mitigation policies are based on noise forecasts, the uncertainties inherent in the forecasts often become a source of contention between the airport and various community groups, because such groups challenge the assumptions behind the forecasts. Relating noise mitigation measures to current, monitor-validated noise may shift the focus of discussion to the criteria for action, that is, to the determination of the noise level at which certain noise mitigation action should be taken. The pertinent question thus becomes how tolerable is noise. Studies dealing with this question show that although individual tolerance toward noise varies widely, community reactions are fairly consistent (*16*). Consequently, standards regarding the acceptability of noise levels are similar in most parts of the developed world. Therefore it may be easier to reach an agreement regarding the criteria for noise abatement action than to agree on a noise exposure forecast. Such agreements may help reduce the mistrust that often characterizes airport-community relationships.

Although this approach may seem fairly straightforward in theory, a number of difficult issues have to be addressed before it can be applied.

The first issue is the time span over which noise should be measured before a decision regarding treatment can be made. This issue has a number of facets. First, during this time span residents are exposed to excessive noise levels. The time should be minimized, therefore, to reduce exposure. Second, the length of time should allow for short aberrant runway use patterns attributable to weather or runway conditions; that is, high noises for relatively short, infrequent periods of time should not lead to major outlays on treatment. Third, it would be inefficient to treat areas that can be expected to be relieved as a result of noise reduction at the source, whether through aircraft turnover to stage three or as a result of changes in use patterns (following the construction of a new runway for example).

The second issue is how to relate treatment to zoning variances. It is socially inefficient for an airport to monitor and treat residences that were permitted through a zoning variance, because the airport is adversely affected and public welfare is not improved (*17*). Any application of this approach thus has to differentiate residences according to the circumstances under which they were built.

A third issue is how to provide the airport with a continuing incentive for noise reduction. Even after treatment, further noise reduction may be desirable, where possible, because in most cases treatment does not eliminate annoyance. If a single criterion for treatment is adopted, the airport would have no further incentives to reduce noise after the eligible affected residences have been treated.

Finally, the criteria have to allow for priorities in treatment. Soundproofing and relocation costs are among the most expensive noise mitigation measures (*1*). It is thus probable that many airports would not have the resources to soundproof or compensate all the residents in areas considered unacceptable (usually above 65 L_{dn}). There would be a need for staggering the expenses according to the severity of the problem and the resources available for noise mitigation.

THE BEN-GURION AIRPORT EXPERIENCE

Ben-Gurion Airport, Israel's main international airport, recently adopted this approach. The airport is located at the center of the country, surrounded by both urban and rural communities. It is near major transportation arteries, and is thus expected to remain Israel's main civilian airport in the future. Currently it has two intersecting runways. To allow the airport to fulfill its role in the future, a third runway was proposed. Discussions regarding it began in the late 1970s as part of a National Masterplan for airports. Communities under the approach to the proposed runway opposed it vigorously. By 1984 discussions reached a deadlock. To break out of the deadlock, the National Planning Board established an ad-hoc committee, headed by the Environmental Protection Service, to propose a noise abatement plan. A number of runway use patterns were discussed, including an "open V" pattern and a "noise sharing" formula. No agreement was reached regarding the best runway use patterns or a noise exposure map. Finally a "flexible plan" was adopted whereby the Airport Authority would not be limited as to the runway use pattern, but would have to treat residences where monitored noise exceeded certain levels. In addition, a noise zone and accompanying building limitations were agreed upon.

The criteria for treatment have three tiers. Immediate treatment is prescribed when noise exceeds 72 L_{dn}. If the measured noise in any year exceeded 70 L_{dn}, but was below 72 L_{dn}, treatment was required unless the airport managed to reduce the noise to levels below 68 L_{dn} for the succeeding 5 years (that is, if the noise exceeds 68 L_{dn} in any one of the following 5 years treatment would be required). In areas exposed to monitored noise levels between 68 L_{dn} and 70 L_{dn}, treatment would be required unless noise is reduced to levels below 68 L_{dn} within 5 years. This staggering of treatment requirements assures that the airport will have a continuing incentive to operate in a noise-sensitive manner. It also assures that the priorities for noise treatment will be based on noise exposure. Thus the residents subject to the highest noise exposure levels will be treated first. Furthermore, the 5-year interval between the time a residence is exposed to noise levels between 68 L_{dn} and 70 L_{dn} and the time the airport is required to treat it allows long-term improvements in noise emissions at the source to reduce the noise at the margins, thus saving costs.

The L_{dn} measurement used in these provisions is based on the noisiest 6 months of a year. Thus a full year of monitoring is required before treatment can be mandated. This should prevent aberrant patterns from unduly influencing the noise exposure map on which treatment decisions are made. The problem with this approach is that no account is taken of peak noise levels.

In addition a noise exposure map will be prepared, as a base for noise-related zoning. This map will be based on the Airport Authority's 5-year forecasts. Because exact future runway use patterns are unknown, the estimates for runway use will be weighted by 2.5 per runway. The noise contours thus will be clearly excessive, ensuring that residences will not encroach on areas that may be subject to high noise levels in the future. This high weighting is made possible by the high degree of government control over land in Israel. Most of the lands affected by noise from Ben-Gurion Airport are owned by the Israel Land Authority, a government entity. Consequently, the excessive building limitations do not require almost any compensation.

The noise zone is divided into four noise exposure areas. Between 60 and 65 L_{dn} all activities will be permitted. However, noise-sensitive uses will be required to be soundproofed at the developer's expense. Between 65 and 75 L_{dn} no new residential development will be approved. Improvements of existing residences will be allowed only with soundproofing. No sensitive activities will be allowed if levels exceed 75 L_{dn}. Nonsensitive activities, such as industry, would be allowed only with noise treatment. Variances from these regulations can be approved only by a special committee that will determine the conditions, if any, under which such variances may be granted.

These provisions will ensure that the airport will not be forced to treat any new developments. The inefficiency caused by residential encroachment is thus avoided.

CONCLUSIONS

This paper suggests an approach to airport noise mitigation based on current noise maps. By ensuring that noise abatement expenditures are a function of actual exposure rather than forecasted exposure, this approach provides a more cost-effective abatement strategy than current policies, which base receptor-oriented mitigation measures on forecasted noise exposure maps. This paper has shown such forecasts to be inherently uncertain. By relating airport actions to noise abatement expenditures, this approach also provides airports with an economic incentive to determine runway use patterns and operating procedures so as to minimize noise exposure. Because this incentive system is based on costs of noise mitigation, it may be more equitable than an incentive system based on the cost of litigation.

A number of practical issues have to be addressed before such an approach can be implemented. They include the determination of the time span over which noise modeling and measurements have to be conducted before action is undertaken; the relationship with noise-based zoning; the determination of priorities in treating residences exposed to noise levels considered unacceptable; and the provision of continuing incentives for airports to limit noise exposure.

At Ben-Gurion Airport in Israel, where such an approach has been adopted, a number of measures are used to address these issues. Multitiered criteria for treating residences provide both a measure to determine treatment priorities and a continuing incentive for airports to operate in a noise-sensitive manner. Only the residences affected by the highest levels of noise will be treated immediately. Residences in lower tiers will be treated only if noise is not reduced over a specified period of time. The time span of noise measurements should be approximately a year to prevent aberrant patterns from unduly affecting treatment decisions. Some account, however, should be taken also for peak noises. Zoning is based on forecasted noise maps. Variations from such zoning should be conditioned on soundproofing at the developer's expense.

Both this approach and the often suggested noise fees may improve noise abatement efficiency. This approach, however, may be easier to implement because it does not require estimating damage functions or future abatement costs. By improving efficiency, it enhances the competitive position of the airport. Furthermore, it shifts the focus of public debate from the assumptions underlying the noise exposure map to the criteria for noise abatement action, reducing community opposition to much-needed infrastructure improvements. This approach thus may hold some promise also for airports in the United States.

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