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MODEL FOR ASSESSING AIRPORT COMMUNITY NOISE IMPACT

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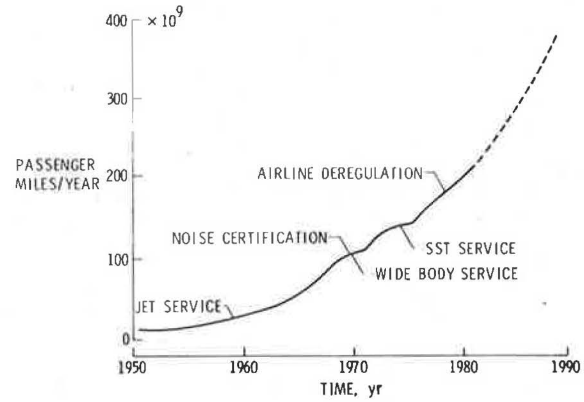
Abstract

A model is described which has been designed to predict aircraft noise impact in an airport community. The model explicitly takes into account community noise levels, population distributions, and human subjective response to noise. Algorithms upon which the model is based are described, as is the computer implementation of the model. A number of examples are given which illustrate how the model has been applied to quantitatively assess the reductions in noise impact associated with such candidate countermeasures as runway re-orientation, population-minimal ground tracks, and soundproofing of homes in the airport community.

Introduction

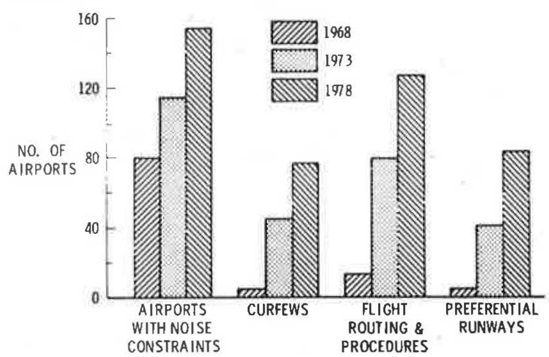
This paper describes an airport community noise impact model which has been developed at the National Aeronautics and Space Administration (NASA) Langley Research Center. The model is designed to quantify the noise impact in the airport community associated with aircraft operations for a given operating scenario. Figure 1 provides some background, by indicating the growth of the U.S. air carrier service in the last decade to the present extrapolated into the next decade. A number of milestones are identified in this figure which are considered to be important with respect to community noise impact. The most recent of these is airline deregulation. It is difficult to determine exactly what effect this will have on the overall trend, but to the extent that it does affect the trend, some accelerating effect would be expected. In any case, it can be anticipated that the United States air

Figure 1. Growth in U.S. air carrier service.



transportation system is going to continue to grow into the next decade. Because of the sustained growth in the air transportation industry in the United States, a number of airport communities have taken steps to deal with the noise problems that are associated with that growth. This is indicated in Figure 2 which shows that in the ten year period from 1968 to 1978, the number of airports with some sort of noise constraints has essentially doubled. These constraints take different forms, some of which are indicated in Figure 2. Curfews,

Figure 2. Noise constraints at major world airports.



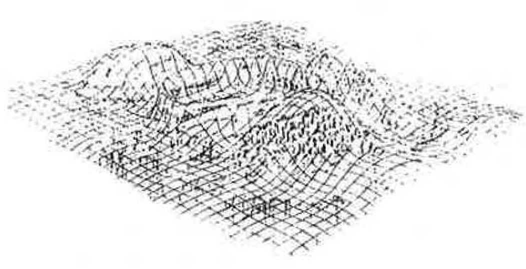
noise minimal near-terminal routing, alternative take-off and approach procedures, and preferential runway systems, all of these noise countermeasures have one thing in common, namely a severe impact on the air transportation system which makes them all very costly in one form or another.

Many of these noise countermeasures are applied in a way which does not bring a great deal of technology to bear on the noise problem. It is generally difficult to determine exactly how much noise relief is associated with a particular preferential runway scheme, for example. It is very easy to quantify the cost associated with these countermeasures, but not nearly so easy to quantify the corresponding benefits in noise relief. To address this problem, a model was developed at NASA Langley in an attempt to clearly quantify the benefits of noise countermeasure options. The approach employed was to make use of as much existing technology as possible. The three major elements of the modeling process are noise, population, and human subjective response. In the present approach existing models of airport noise, population, and human response were incorporated into a unified noise model. Typically, the model would be used to quantify the impact of the current operating scenario, along with a proposed countermeasure, to determine the difference in noise impact. The model will not suggest that a certain degree of impact reduction is worth the cost associated with it, but it can provide quantitative information to decision-makers, which indicates the extent to which some relief is to be achieved with a given proposed operating procedure.

Model Elements

As noted earlier, the three elements of the model are noise, people, and response. The first element, noise, is represented in the community with a standard footprint model defined by contours of constant noise exposure around the airport. The Federal Aviation Administration (FAA) Integrated Noise Model is used for this purpose, although any model describing the distribution of noise levels in the community would be appropriate. This noise footprint model was combined with the population distribution derived from the United States census data. The entire 1980 U.S. census data base is built into the model. Thus the contours of constant noise exposure for any airport in the United States can be used to determine the number of people and certain demographic information about those people (the demographic information available in the census data) for all persons residing within a given noise contour. Noise impact is obtained by combining the distribution of noise levels with the distribution of people and determining the extent to which those two distributions match up. The two are tied together by a dose response relationship which is some measure of human response to noise as a function of noise level. Typically, the number of persons exposed to a particular noise level would be determined and the appropriate transfer function applied to estimate the number of people impacted adversely. In this manner the effects of candidate operating senarios can be evaluated.

Figure 3. Airport community noise impact.

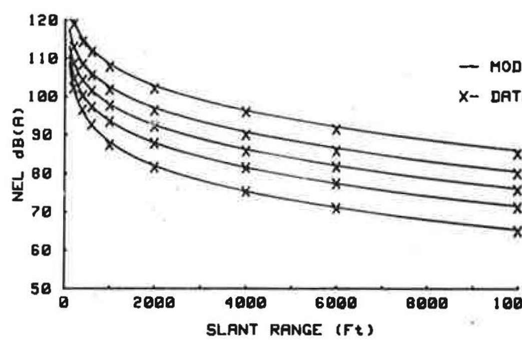


An artist's conception of airport community noise impact is shown in Figure 3. Overlaid upon this community is a "net", the height of which (above the surface of the community) is meant to be conceptually proportional to noise impact. Thus, a relative bulge in this net, implies relatively high noise impact, and dips in the net imply less impact. Notice that over the runways the net is concave. Even though the noise levels are the highest there, people are absent, so in the context of the model, there is no impact. Further out, where noise levels might be lower, the concentration of people becomes more dense. So although noise may be less, quite a few more people are being impacted, and consequently the noise impact is greater there. The point to note is that population distribution is equally important as the noise distribution for assessing noise impact.

Model Implementation

The noise impact model was designed to run on a large main frame computer, such as the CDC Cyber 170 series computers at NASA Langley. However, this computer system is very large, expensive to use and is not available to a wide range of potential end-users. It would therefore be useful to implement this model on a smaller computer such as a "desk top" microcomputer system, so that it can be more readily accessed by end users. To do that, certain simplications in the Integrated Noise Model are required in order to implement it on a smaller computer. The Integrated Noise Model contains noise exposure levels in terms of DBA as a function of slant range for various engine thrusts in tabular form. The x's in Figure 4 represent the tabular data in the Integrated Noise Model. For each of the 40 aircraft types in the model, and for each of the seven stage lengths for every aircraft, there is a table of noise, engine thrust, and slant range data in the Integrated Noise Model. That is too much data to keep in a small desk top system. To work around this the data were at the functional

Figure 4. Prediction of noise levels.

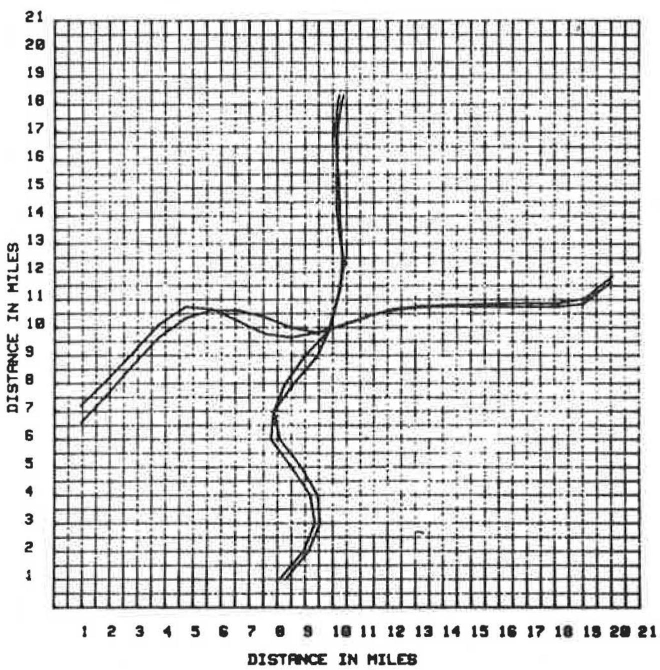


forms indicated in Figure 4. So for each aircraft type, it is only necessary to store the relatively small number of coefficients, necessary to define these curves. That also circumvents the interpolation problem present with tabular data, and reduces the time overhead associated with making interpolation calculations. The residuals (the difference between the mathematical model values and the experimental data that comes from the Integrated Noise Model) are throughout this entire range of slant ranges less than .05 decibel. The Integrated Noise Model also describes departure profiles by storing tables of thrust, altitude, speed, and ground track distance for each take-off procedure. A different set of tables is stored for each aircraft. Since it is costly to do this on a desk top microcomputer implementation of this model, the data have again been fit with a functional form, storing only the coefficients of this function for each take-off procedure.

Model Application

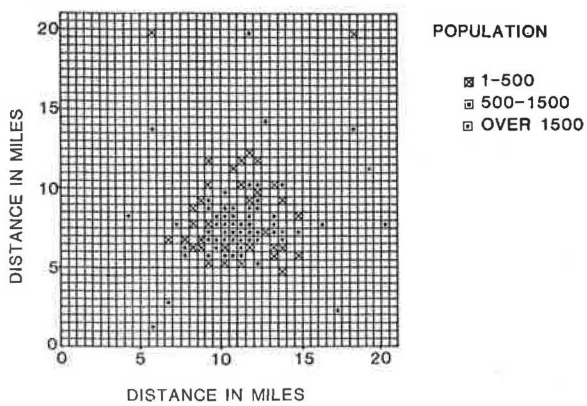
Comceptually, the model starts with distributions of noise levels in the community, overlays those on population distributions, and relates those two through a dose response relationship. Figures 5-8 describe how this is done in the computer. Figure 5 illustrates two runways for an example airport. The curved lines represent ground tracks, the two dimensional projection on the earth's surface of the three dimensional trajectory of the aircraft coming into this airport. The model overlays a grid

Figure 5. Airport community grid.



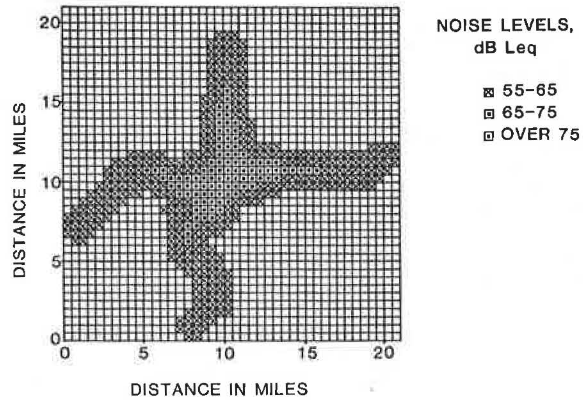
structure over the community 21 miles by 21 miles; each grid cell is 1/2 mile on a side. That serves as a frame of reference. The number of people is determined for each cell as illustrated in Figure 6, in which population densities are coded on a low-medium-high basis to highlight population hotspots.

Figure 6. Airport community population distribution.



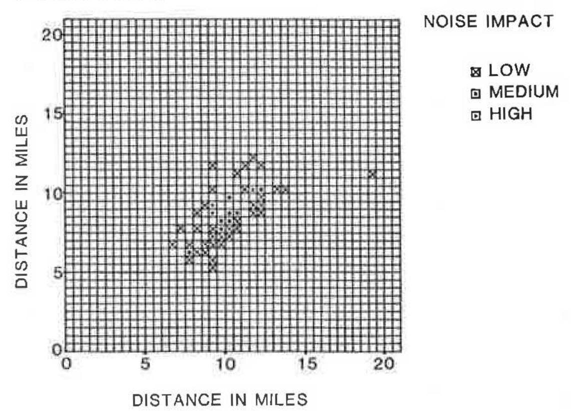
If the task of an airport operator is to design ground tracks which avoid population centers, then output such as that in Figures 5-8 would be helpful.

Figure 7. Airport community noise distribution.



The next step would be to determine the distribution of noise levels in the community. The noise level is calculated in each cell for which it is above a certain threshold, such as an annoyance threshold. In this case such a threshold is 55 dB on the LEQ scale. In this particular airport community, most of the noise levels are over unpopulated areas. Prior to this concept of introducing population distributions, noise "footprints" were the primary tool for assessing noise impact, with the implicit assumption that the noise impact is in some sense proportional to the area under this footprint. That's a concept that has a certain amount of intuitive appeal, but it is just as important to take into account the population distribution as the noise distribution. Figure 8 displays the only

Figure 8. Airport community noise impact distribution.



cells in the community which are populated and are exposed to levels above 55 dB. This gives an entirely different perspective from either the footprint alone or the population distribution. To quantify the noise impact, the model multiplies the number of people residing in each cell by the total amount of energy which impacts that cell in a twenty-four hour period. This number is called the level-weighted population, and it is larger for dense populations exposed to a given noise level, or for a given population exposed to higher noise levels. The level-weighted population in each cell is summed for the entire airport community to yield a single number descriptor, the total level weighted population, and it is that number which the model uses to quantify impact.

The model has been used in a number of studies to date. For example, a general aviation airport in Florida was considering a number of runway alternatives to accommodate additional traffic forecasted into the year 2005. Three alternatives in addition to maintaining the status quo were considered. The status quo and the three change alternatives were analyzed with this model. It was found that for that particular airport, the noise minimal runway orientation would result in the equivalent of something over one dB in equivalent source noise reduction over the status quo.

More dramatic results were obtained when ground track optimization was considered at a major midwestern airport. There is an algorithm in the model which can determine the ground tracks which fly over the smallest number of people in a given airport community. It is called the shortest path algorithm because it finds the shortest path through population space from the runway to a community exit point. When it was assumed that aircraft were flying population minimal tracks as compared with conventional ground tracks, a reduction in level-weighted population was predicted equivalent to something in excess of 4 decibels reduction in source noise for each airplane flying in the fleet. At a small regional airport, alternative runway use rates were considered. Runway use rates were found which did not violate wind constraints, and yet resulted in an overall reduction in the noise impact in the community equivalent to more than three decibels equivalent source noise reduction.

The Environmental Protection Agency (EPA) has used this model to look at the 70 largest airports in the United States to consider the effects of soundproofing all homes inside the 65 dB contour. The costs of such a countermeasure were large, and it was important to be able to quantify the benefits. The soundproofing program was predicted to achieve the equivalent of approximately 3 dB per aircraft source noise reduction.

Concluding Remarks

The purpose of this paper is not to make a particular point about the degree of noise impact associated with a given operating scenario but simply to point out the types of scenarios which could be evaluated at a given airport. There are other operating scenarios as well that could be studied.

The noise model described in this paper can be used to quantify the benefits associated with a number of noise abatement operating scenarios. Sometimes a particular operating scenario will be found to have significantly less benefit than assumed, but such a null result can also be useful by indicating that a particular change may not be effective. The model can, therefore, indicate if a proposed countermeasure will be effective at all, and if so, how much more or less effective than competing countermeasure proposals. An informed decision can then be made, based on both the cost of the countermeasures, and a quantitative indication of the benefit.

APPLICATION AND VALIDATION OF A MODEL FOR PREDICTING AIRCRAFT AND AIRPORT COMPATIBILITY

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Abstract

Aircraft/airport interface problems can be predicted in initial design stages. A methodology has been developed to analyze and predict potential and known effects of aircraft or airport design. Central to the methodology is a generalized prediction model. In this investigation, the model was applied to a specific dramatic situation. A questionnaire was devised and used to ascertain how well historic information when applied to the model agreed to known impacts identified by the questionnaire. The results are that the overall analysis methodology and the prediction model are effective in reproducing "potential" problems in compatibility of an historic case. The high correlation of the validation should substantiate the workability and capability of the prediction model to analyze problems in compatibility in an efficient and meaningful way.

Introduction

Achievement of compatibility between aircraft and airports requires consideration of many factors pertaining to the configuration and operation of both aircraft and airports (1). Methodology is required to systematically analyze these factors in such a way that design and operational impacts within the interface can be predicted and evaluated in a meaningful and efficient manner.

There are strong motivations for doing these prediction analyses from a systems point of view. First, the comprehensive nature of potential problems can be overlooked if a total systems perspective is not maintained. Second, if prior knowledge of potential compatibility problems can be achieved, essential goals within the industry can also be achieved in an optimum way. For example, if one considers that profitability, service and safety are key air transport goals, prior knowledge of potential safety problems, operational constraints, and/or hidden operational costs will enhance the achievement of goals and improve decision making outcomes. In the age of deregulation, these motivations may be most critical to the industry's health and well being or very survival. Additionally, these analyses must consider addressing both existing compatibility problems and evaluating proposed alternative configurations or operations.

To fill a void in aircraft and airport compatibility analysis techniques, a systems approach has been recently developed which has at its core a generalized prediction model (2). It will be referred to as the Virginia model. The acceptability of the prediction model for application to real-world problems requires that the workability and capability of the overall methodology be demonstrated and that the validity of the prediction model be assessed.

The purpose of this paper is to report on a first effort to validate the Virginia model (3). In this investigation, the model was applied to a specific dramatic situation which arose from a past experience. A primary objective was to ascertain how well predicted impacts agreed with the opinion of knowledgeable specialists involved in that situation.

The specific situation examined was the introduction of the Boeing 747 by United Air Lines into