U.S. Civil Aircraft Noise Annoyance Survey Design

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ABSTRACT
Community expectations with respect to noise exposure are changing and what might have been acceptable 15 years ago might not be today. While noise levels might be the same or less due to quieter aircraft, the volume of flights over communities as well as shifts in arrival/departure patterns seems to be shaping perceptions. The Federal Aviation Administration (FAA) initiated a new community survey to investigate community response to aviation noise. This survey is collecting data from a representative sample of residents in households surrounding airports and relating the reported annoyance to modeled noise exposure level at that respondent’s location. The survey will result in an up-to-date nationally applicable aircraft noise dose-annoyance response relationship. Once created and validated, the FAA will use the relationship, along with additional research the FAA is performing on aviation noise impacts, to determine what, if any, changes in noise regulatory policy or guidance are warranted. This paper describes the design instruments, criteria for subject and airport selection, and the precision considerations for the empirical dose-response curve.

Keywords: Annoyance, Dose Response, Survey

1. INTRODUCTION

The Federal Aviation Administration (FAA) has launched a series of noise research projects to update the scientific foundation for U.S. civil aviation noise policy. This research is focused on advancing our understanding of aviation noise and how it impacts annoyance, children’s learning, health, and sleep disturbance. The goal of the research is to improve the understanding of the effects of civil aviation noise in these areas and to ensure that the U.S. civil aviation noise policy continues to be based on the best available scientific information (1).

The U.S. aircraft noise policy was first established in the 1970s. Since that time the national airspace system has undergone major modifications. Since the mid-1970s, there has been a 95% reduction in the number of people exposed to significant noise, defined as day-night average sound level (DNL) 65 dB and greater, in proximity to U.S. airports from over 7 million in 1975 to 340 thousand in 2014. However, this order of magnitude reduction in population exposure has not been accompanied by a comparable decrease in the concerns being expressed by residents in communities around airports. The apparent disconnect between noise exposure and the concerns expressed by airport communities about aircraft noise indicates that research is needed to better understand the public perception of aircraft noise.

Provided that they are conducted without bias and utilize methods that are widely accepted by the scientific community, community surveys provide a means to quantify people’s attitude towards aircraft noise. For aviation, community surveys have generally collected data in the form of dose response curve showing the percent of residents that are “highly annoyed” (percent HA) at a given noise exposure level. The last comprehensive evaluation of community annoyance presented their data in the form of a logistic regression analysis:

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Percent \ HA = \frac{100 \exp(\beta_0 + \beta_1 DNL)}{1 + \exp(\beta_0 + \beta_1 DNL)}.
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where the parameters were estimated as \(\beta_0 = -11.3\) and \(\beta_1 = 0.14\). Given the apparent disconnect between population exposure to significant noise and the community’s response to aircraft noise, and the fact that this relationship was established over two decades ago, there is a need to develop an updated dose response curve to understand if community perceptions have changed over time.

Communities surrounding twenty airports nationwide are being surveyed, making this one of the most comprehensive aircraft noise studies using a single survey instrument ever undertaken. This survey is collecting data on annoyance from a representative sample of residents in households surrounding airports and relating the reported annoyance to modeled noise exposure level at that respondent’s location. These data will permit the creation of an up-to-date nationally applicable civil aircraft noise dose-annoyance response relationship. The primary research question for this study is whether there has been a shift over time in annoyance to civil aviation noise at varied sound levels. This paper describes how the survey was designed. The results of the survey will be presented in future publications.

2. SURVEY DESIGN CONSIDERATIONS

Given the time lapse since the last U.S. airport community noise survey, the FAA based the methodology on a research project conducted by the Airport Cooperative Research Program (ACRP) which is managed by the Transportation Research Board, a division of the National Research Council, which in turn is administered by the National Academies of Sciences, Engineering, and Medicine. The research project’s goal was to develop the framework for a large-scale social survey. The project, called Project 02-35, Research Methods for Understanding Aircraft Noise Annoyance and Sleep Disturbance, developed the framework and validated that framework using three U.S. airports (3), (4).

Project 02-35 results were adapted for the national survey. The design instruments, the criteria for subject and airport selection, and the accuracy of the empirical dose-response curve described in Project 02-35 were all considered when developing the national survey.

2.1 Airport Selection through Sampling

For the national survey, twenty airports are being surveyed simultaneously over the course of a year. This approach ensures the survey captures any seasonal effects on response and minimizes the chance that the names of the airports become known. The names of these airports will not be disclosed until the end of the study to preserve its scientific integrity. The twenty airports were chosen to represent airports across the U.S. and were selected using a balanced statistical approach (5).

Prior to embarking on the balanced sampling, a down selection of airports was completed. The down selection was necessary to ensure that sufficient residences would be available for sampling at the higher noise levels. Hence, airports needed to meet the following criteria to be considered for the survey:

- have at least 100 jet operations per day,
- have at least 100 households exposed to aircraft noise of Day-Night Average Sound Level (DNL) 65 dB or above, and
- have at least 100 households exposed to levels between 60 dB and 65 dB.

There are 95 airports with civil operations in the U.S. that met these criteria of eligibility.

A balanced sampling method was used to obtain a sample that reflects various factors in the same proportion as occurs in the overall set of airports. It is applied when a stratified sample will not work because the number of desired stratification factors is larger than the sample size will support.

FAA designated four of the ninety-five airports to be in the sample due to the number of people exposed to aviation noise and to the number of operations at those airports. In addition, the three airports from the ACRP pilot study were excluded from the list of ninety-five airports as their data are already available. Sixteen airports were selected from the remaining eighty-eight airports based on a list of factors that were chosen to best represent the variety of airports characteristics that may affect how people react to aviation noise. These factors were:

- FAA region: The sample was to be representative across all FAA regions (except Alaska). This factor was used to ensure geographical representation.
- Average daily operations: The selected sample needed to represent both small and large airports. Therefore the median for all 95 airports was chosen as the division to ensure a
range of airport sizes.  
- Percentage of nighttime operations: It is possible that a larger percent of operations at night may be associated with higher annoyance responses. Hence, the division used for this factor was 20 percent of operations at night, rounded from the median value of 18 percent at night.  
- Average daily temperature: During Project 02-35, one of the few airport variables that were found to affect annoyance is climate, with warmer climates resulting in higher annoyance. The divisions based on average daily temperatures were selected to insure that all climate zones of the U.S. would be sampled. The proportions of airports in the sample were balanced between airports with daily average temperatures above 21.1 degrees C (70 degrees F), below 12.8 degrees C (55 degrees F), and with temperatures between these two numbers.  
- Fleet mix ratio: It is possible that for a given noise exposure, annoyance reactions may be different depending on fleet mix. Smaller, lighter aircraft generally tend to be somewhat quieter than larger heavier aircraft. Consequently, greater numbers of overflights of the smaller aircraft would be required to produce a noise exposure equivalent to that produced by a lesser number of large aircraft. A ratio of light to heavy aircraft of 1 was selected as the dividing value.  
- Population within five miles of airport: Population within 8.04 km (5 mile) radius of each airport was determined based on U.S. Census data, and a mean of 230,000 residents was used to divide the sample. This was used to ensure a range of population density around airports.

Table 1 illustrates each of these factors and the division used in the balanced sampling. The sixteen airports were selected randomly using a balanced probability sampling approach. These factors were used in such a way that the percentage of airports in each category approximates the percentage in the full set of 95 airports. In addition, the FAA plans to include results of the surveys of the three airports studied during Project 02-35 in the final dose-response curve derivation.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Factor Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Located in each of 8 FAA regions</td>
<td>No division. Include airports in all regions except Alaska</td>
</tr>
<tr>
<td>Average Daily Operations</td>
<td>Less than 300 operations</td>
</tr>
<tr>
<td>Percent nighttime operations</td>
<td>Less than 20%</td>
</tr>
<tr>
<td>Average Daily Temperature</td>
<td>Less than 12.8 degree C</td>
</tr>
<tr>
<td>Fleet mix ratio</td>
<td>Less than 1</td>
</tr>
<tr>
<td>Number of People Living within 8.04 km (5 Miles) of the Airport</td>
<td>Less than 230,000</td>
</tr>
</tbody>
</table>

### 2.2 Population Selection

The second stage of the sampling process was to select addresses that are within the desired ranges of noise exposure. For each airport selected, noise exposure contours were determined using the FAA’s Integrated Noise Model version 7.0d. These contours were used to stratify addresses at each airport into groups based on ranges of DNL exposure. Five DNL strata were used: 50≤55, 55≤60, 60≤65,

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4 The INM has been replaced by the Aviation Environmental Design Tool (AEDT) as of May 2015.
65 ≤ 70, and above 70 dB. If an airport had too few people at higher noise exposure levels, the strata was defined alternately as 50 ≤ 55, 55 ≤ 60, 60 ≤ 65, and above 65 dB or as 50 ≤ 55, 55 ≤ 60, and above 60 dB. The stratification guarantees that the sample at each airport contains households with widely distributed values of noise exposure. Addresses with levels of DNL 50 dB or lower were excluded from the sample.

Computation of noise contours and noise metrics for the twenty airports for an entire year of operations was based on radar flight track data (Performance Data Analysis and Reporting System or PDARS) and associated flight specific information, (e.g., aircraft type, time of operation, and distance flown). The noise contours produced were then used to select candidate survey respondents. For this purpose, the respondent sampling required contours in GIS format (ESRI shapefiles). These files were used to overlay the contours on housing addresses, and random samples of addresses were selected in each DNL 5 dB contour range from DNL 50 dB to DNL above 70 dB. The addresses on the U.S. Postal Service Computerized Delivery Sequence File were used as the household sampling frame. These addresses were geocoded to the appropriate noise strata.

2.3 Data Collection Process

As this survey will result in the single largest collection of airport community noise data that has been taken at one time, it is important that the same survey instruments and data collection procedures be used for all of the airports, and the survey be conducted during the same time period at all airports. These uniform procedures will result in data that can be compared across airports. It will also result in the development of sound scientific evidence that could be used to construct a national dose-response curve relating annoyance levels to civil aircraft noise exposure.

The survey instrument was developed and validated through Project 02-35, which acquired dose-response data from three airport communities. The survey questionnaires were also reviewed by independent experts.

The national study will collect data using both a paper mail survey and a computer-assisted telephone interview (CATI). Project 02-35 found mail and telephone surveys to be statistically equivalent in terms of the resulting annoyance data. Additionally, the percent of subjects responding to the mail survey is significantly higher than telephone survey response rates (35.1 percent for mail relative to 12.1 percent for phone). Hence, for the twenty airports, the mail survey will be the primary method to collect the response information that will be used to construct the dose-response curve. The mail survey will also ask the respondent if they would be willing to participate in a telephone interview. If the respondent answers yes, then they are added to a database that is resampled for a telephone interview. Given that the telephone interviews are a resampling of the mail survey respondents, the telephone annoyance response will not be used to inform the dose-response curve.

When completing the mail survey, all sampled addresses will be contacted between 2 to 4 times, depending on when the questionnaire is returned. The contacts will include: 1) an initial survey packet; 2) a thank-you/reminder postcard approximately one week after the initial survey mailing; 3) a second survey package mailing two weeks after the thank-you/reminder postcard (three weeks after initial survey mailing); and 4) a third survey package mailing three weeks after the second survey package mailing (six weeks after initial survey mailing). The telephone interview asks additional questions about the respondent’s thoughts on personal perspectives and environmental concerns that have been hypothesized to be related to annoyance. These data will be used to explore factors that could correlate with annoyance. The telephone interview will be conducted with an interviewer being assigned eligible households via an electronic call scheduling system. This system prioritizes calls to occur when the respondent is most likely to be at home and it allows the interviewer to set appointments for any time that is convenient to the respondent. As the interview proceeds, the responses are entered directly into the database by the interviewer. These data are then stored in a centralized database that is used for analysis.

The survey will be conducted once per respondent and one response will be collected per household. No responses will be collected electronically. Based on experience from Project 02-35, it is expected that the mail questionnaire will take approximately five minutes and the telephone interview approximately twenty minutes to complete.

Several different tests were conducted in Project 02-35 for non-response bias. One was to conduct a response propensity analysis, which correlated socio-demographic characteristics and noise levels to response. This analysis did not find any evidence that noise level was related to non-response, which would be expected if the pattern noted in the questions was significant. Given the lack of any evidence
of non-response bias, the proposed design is following the recommendation of the Project 02-35 study report by increasing resources into boosting the response rate to the mail survey by using incentives, express mail delivery and distributing a Spanish-language questionnaire. All of these measures have been proven to be effective in improving response rates.

2.4 Sample Size and Accuracy

This survey will collect public perception data from a representative sample of approximately ten thousand residents in households surrounding twenty airports. The results will relate the reported annoyance to the computer modeled noise exposure level at that respondent’s location.

The number of addresses selected is based on the findings of Project 02-35. Three types of outcomes in that study affected the number of addresses ultimately needed: 1) precision of results versus sample size, 2) response rates, and 3) comparability of telephone survey and mail survey results.

The number of airports and sample size for each airport were selected to develop an accurate estimation of the curve describing the national relationship between the percent of the public that is highly annoyed and noise exposure. Table 2 gives the expected number of responses calculated using the estimated response rate. When determining the number of airports and respondents around each airport to survey, variability around the final dose-response curve was considered. There are two components to the variance of the estimated curve: the first is the variability among respondents within an airport community, and the second is the differences from one airport to another. Increasing the number of respondents for one particular airport community only addresses the first source of variability: increasing the number of airports reduces both sources of variability. With the survey including twenty airports, it allows the relationship to be estimated precisely using a smaller sample size within each airport community. This means that increasing the number of addresses per airport beyond the 500 mail survey responses results in little increase in precision for the national relationship.

| Table 2. Expected number of respondents for each airport, and for the study as a whole |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Noise Exposure Range, dB DNL    | 50-55           | 55-60           | 60-65           | 65-70           | 70+             | Total           |
| Each airport, mail              | 100             | 100             | 100             | 100             | 100             | 500             |
| Total, all airports, mail       | 2,000           | 2,000           | 2,000           | 2,000           | 2,000           | 10,000          |
| Each airport, telephone         | 21.4            | 21.4            | 21.4            | 21.4            | 21.4            | 107             |
| Total, all airports, telephone  | 428             | 428             | 428             | 428             | 428             | 2,140           |

As the goal of the effort is to minimize the confidence bounds on the resulting dose-response relationship consistently across all noise exposure levels, the sampling scheme needed to be considered. In each 5 dB noise stratum, approximately equal numbers of respondents will be sampled. To achieve these equal sample sizes, however, in most airports a much higher sampling fraction will be needed in higher noise strata than in lower noise strata given that fewer people are exposed to higher noise levels. The margins of error are larger for the national airport curve than for a curve from a single airport because of the airport-to-airport variability, which is not a factor in the curve from a single airport.

There is evidence that annoyance reaction vary between residential communities and from airport to airport (6). The telephone interview questionnaire is intended to provide supplementary information on attitudes of residents around the selected airports to help determine the reasons for any observed differences. The telephone interview does not have the stringent precision or response rate requirements of the mail survey as it won’t be used to estimate the dose-response curve, instead its intent is to analyze why there are differences in residential reactions among airport neighborhoods. Therefore, a sample size of 100 completed telephone interviews per airport was deemed to be sufficient. The telephone survey will also use equally-sized samples.
3. CONCLUSIONS

This paper described the process and methodology that is being used to conduct a nationwide survey of communities around U.S. airports. Twenty airports are being surveyed over the course of a year to define an updated relationship between civil aircraft noise and annoyance. A balanced sampling approach was used to select the airports that are being surveyed. This survey will collect data from a representative sample of approximately ten thousand residents in households surrounding airports and relate the reported annoyance to the computer modeled noise exposure level at that respondent’s location. A cumulative national civil airport annoyance curve will be constructed from responses to the mail survey using a logistic regression analysis. Telephone interviews will also be conducted to help us understand the differences in residential reactions among airport neighborhoods.

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REFERENCES