

Residents' Perceptions and Field Measurements of Helicopter Operations

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Despite the considerable research in the area of perceptions and annoyance in relation to noise levels research outside the context of commercial airports and military bases is lacking. Little is known about reactions to helicopter operations in areas where such disturbances are unexpected. Examples of such locations include several national parks and various communities in Hawaii affected by tour operations. A special federal aviation regulation has been enacted for the Grand Canyon National Park, and others may be precipitated from Public Law 100-91. At present, however, no legislative initiatives cover residential communities. The basic question that the research attempted to answer was whether, in towns of low-residential-density, exposure to loud, frequent, or long-lasting helicopter overflights corresponds to a negative attitude toward helicopter tour operations. Perceptual and actual noise measurements were collected, the former with a mail-back questionnaire survey and the latter with an extensive field survey. Investigations in four communities focused on potential relationships between people's annoyance and actual operational characteristics, such as noise intensity, frequency, and overflight duration. The expectation was substantiated that more exposure to helicopter overflights, particularly in terms of frequency and duration, relates to increasing annoyance.

This paper contributes to the existing knowledge of helicopter noise impacts on rural communities by describing the major findings of a study sponsored by the Airports Division of the Hawaii Department of Transportation (HDOT) which, in its role as operator of the statewide system of airports, has been facing a problem of increasing severity in recent years. The 1994 study (1) developed a set of recommendations based on (a) a comprehensive literature review of research in acoustics and prior experience on human response to helicopter noise, (b) the identification of the extent of the problem in rural areas of the state and a comparison of the impact on exposed and nonexposed communities with analysis of a mail-back survey, and (c) the measurement of ambient, traffic, and helicopter noise in exposed communities to either substantiate or refute the findings of the survey.

The major elements of the literature review have been reported (2). The assessment of the problem of helicopter noise and comparisons of the impact on exposed and nonexposed communities also have been reported (3). This last study, stemming from the aforementioned HDOT research grant, addresses the relationship between perceptions and actual measurements from helicopter operations over rural residential areas.

Although considerable research has been done in the area of perceptions and annoyance in relation to noise levels, almost no research has been done outside the context of commercial airports and military bases. Little is known about annoyance at and reactions

to noise in areas where such disturbances are unexpected. Examples of such locations include several national parks and various communities in Hawaii affected by tour operations.

A special federal aviation regulation (SFAR 50-2) has been enacted for the Grand Canyon National Park, and others similar to SFAR 50-2 may be precipitated by Public Law 100-91, which requires that the National Park Service conduct studies and cooperate with FAA for the protection of the environment and ambience in national parks.

At this time, no legislative initiatives cover residential communities. Only FAA's 14 CFR § 135.203(b), for Part 135 operators, requires the maintenance of a minimum altitude of 91.44 m (300 ft) above ground level in congested areas. Note that there is no specification about residences or residential areas. Other operators are required by 14 CFR § 91.119(d) to operate the "in a manner that is not hazardous to persons or property."

The basic question that our research attempted to answer was, Does exposure to loud, frequent, or long-lasting helicopter overflights correspond to a negative attitude toward helicopter operations among low-residential-density towns in Hawaii affected by helicopter tour operations? Emphasis was placed on operational characteristics of helicopter overflights, such as frequency and duration of overflights.

A field measurement survey was conducted on the island of Hawaii because this island has been the nearly exclusive focus of the helicopter noise issue since 1992. Four communities (Keaau, Kurtistown, Mountain View, and Pahoia) were selected as the sites for field measurements. The specifics of field measurement procedures and instruments are given in the next section, along with a description of the research methodology. They are followed by a presentation of the results and the conclusions.

METHODOLOGY AND DATA

The research methodology is shown in Figure 1. It begins with the collection of perceptual and actual field measurements. Perceptual data were gathered with a mail-back questionnaire survey. Actual data on helicopter operations were collected during a field survey of fairly extensive coverage and duration. Various analyses were conducted with the two data sets. For instance, identification of ambient- and helicopter-noise profiles at each station within each community were done with the field data, and estimation of annoyance models was done with the perceptual data. Segments from the two data sets, selected based on zip codes, were also compared to reveal potential relationships between people's perceptions of noise and actual operational characteristics, such as noise intensity, frequency, overflight duration, and combinations of these three descriptors. The data sets are described below.

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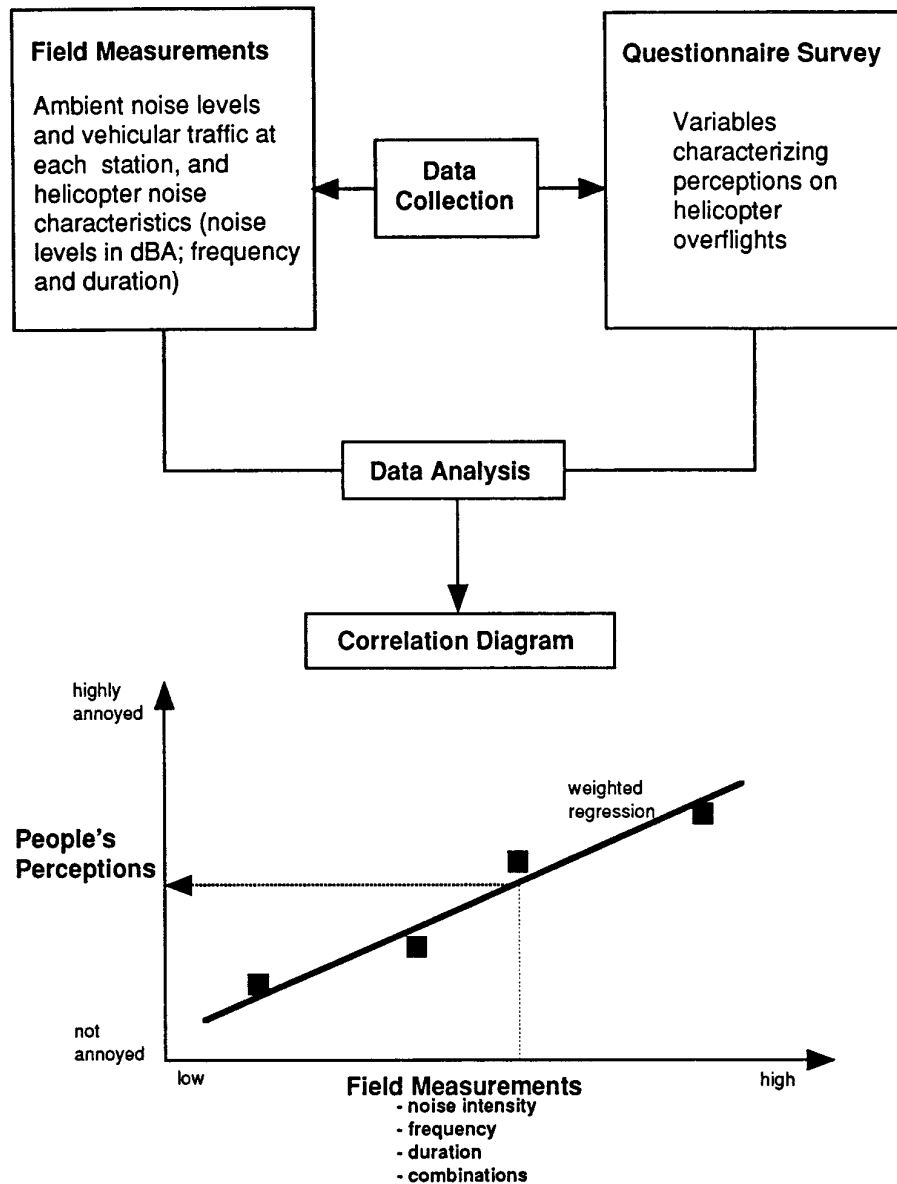


FIGURE 1 Methodology of analysis.

Field Measurements of Helicopter Noise

The noise measurements were taken with a Bruel and Kjaer sound level meter (Precision Integrating Sound Level Meter Type 2230). All measurements were taken in the A scale. To achieve continuous measurements, the noise readings were recorded by using a multimeter (FLUKE 45). The multimeter was used as an interface between the sound level meter and a portable computer, for automatic storage of the noise readings in the computer.

The noise measurements were taken for 2 hrs at every station. The 2-hr span was determined partly by the objective of cover in a multiple stations with limited manpower and the need to replace or recharge the computer's batteries. Two types of noise measurements were taken at every station. The first type was continuous noise measurements taken during the first half hour to identify the

ambient and traffic noise levels. The second type was interrupted noise measurements taken during the remaining 1.5 hr to record only the helicopter noise levels. Noise measurements were taken for 2 days (one on a weekday and the other on a weekend day) in each of the four towns.

Ten days were spent on the east side of the island of Hawaii for to collect noise measurement. (A few days were consumed by reconnaissance, identification of suitable locations for measurements, and inactivity because of heavy rain.) Noise measuring stations were identified within and around the residential areas of each town based on the following selection criteria: The location should be (a) near three or more residences; (b) at least 3 m (10 ft) away from major noise sources such as vehicular traffic, people in the neighborhood, children playing on the street, barking dogs, lawn mowers, etc.; (c) away from tall buildings, large trees, solid fences,

etc., which may bias the readings; and (d) on the side of public property, to avoid trespassing.

Questionnaire Survey

Questionnaires were sent to a random sample of households on the islands of Hawaii and Maui to assess people's perceptions of helicopter noise as experienced in their neighborhood. Overall, more than 1,400 completed responses were received. This part of the research, however, focused on the east side of the island of Hawaii, which is by far the greatest source of helicopter-noise complaints to HDOT's Airports Division. Furthermore, the research focused on four rural communities, which can be readily identified geographically and by zip code (3, p. 70). Geographic identification is necessary so that field measurements are conducted within the boundaries of the communities. By using zip code identification, the field-measured helicopter operations data and perceptions of annoyance can be properly matched and compared.

For purposes of this investigation, only the perceptual responses to the questionnaire were considered. [Analysis of most variables from the survey has been presented elsewhere (3)]. Variables (Y_i), where Y_i equals annoyance, represent each questionnaire statement; they are given in Table 1 with their corresponding statements. The respondents were asked to rate each statement depending on their level of agreement or disagreement with it (e.g., -2 for, "strongly disagree" to $+2$ for "strongly agree").

The first five variables in Table 1 are similar because they assess the people's concerns about the helicopter noise present in their neighborhood. They were combined into a single variable using factor analysis. Application of factor analysis provides the user with the coefficients (factor loadings or weights) corresponding to each variable for the creation of a single variable from a set of given independent variables.

$$Y_F = 0.215 * Y_1 + 0.192 * Y_2 + 0.173 * Y_3 + 0.203 * Y_4 + 0.217 * Y_5 \quad (1)$$

The parameters shown in the equation above result from the execution of factor analysis with SSPS/PC+ using the maximum-likelihood (ML) factor extraction procedure. ML was selected as the most rigorous estimation method available in SPSS/PC+. Y_F is the resultant variable. The χ^2 test (invoked automatically) and the eigenvalues of the five initial factors determined that one factor is sufficient for combining the independent variables Y_1 to Y_5 (Y_F explains 68.7 percent of the variance of these five variables). The Kaiser-Meyer-Olkin measure of sampling adequacy is 0.855, which is rated as "meritorious," whereas for comparison, a value below 0.5 is "unacceptable." The Bartlett test of sphericity is also significant (higher than 99 percent).

The model described by Equation 1 has been estimated from 1,420 questionnaire responses. Its application to this study should be reliable, but its transferability to other locales may be inappropriate because of the homogeneity of the sample (e.g., from rural Hawaii only). However, one may observe that most factor loadings (coefficients) are not considerably far from 0.20, the default weight, which corresponds to the assumption that all Y_i ($i = 1$ to 5) are equally important.

ANALYSIS

Noise profiles were drawn from the half-hour of continuous noise measurements and from the noise levels of individual helicopter overflights. Ambient noise levels and traffic noise levels at each station were identified from the continuous noise profiles. Duration, frequency, and noise are the three helicopter noise characteristics considered for comparison with the perceptual data.

A sample of the data collected in the field is shown in Figure 2. The top graph details the ambient noise level at Station 2 in Kurtis-

TABLE 1 Variables Derived from Perceptual Data

| Variable | Questionnaire statements |
|----------|---|
| Y_1 | I am often annoyed by helicopter noise at my home |
| Y_2 | I am often annoyed by helicopter noise while at work |
| Y_3 | I am often worried that one of the helicopters will crash on my property |
| Y_4 | Helicopter flights disturb my sleep or the sleep of somebody else in my household |
| Y_5 | My household's privacy is invaded by some of the helicopter overflights |
| Y_6 | Noise from cars and trucks is very annoying in my neighborhood |
| Y_7 | Noise from work activities, hunters or other people is very annoying in my neighborhood |
| Y_8 | Noise from nature is very annoying in my neighborhood |
| Y_9 | Government regulators should adopt stricter helicopter noise regulations |
| Y_{10} | Helicopter pilots can fly in ways which would lessen noise in my neighborhood |
| Y_{11} | Yesterday I heard helicopter noise when I was at home during day time |
| Y_{12} | Yesterday I heard helicopter noise when I was outdoors during day time |

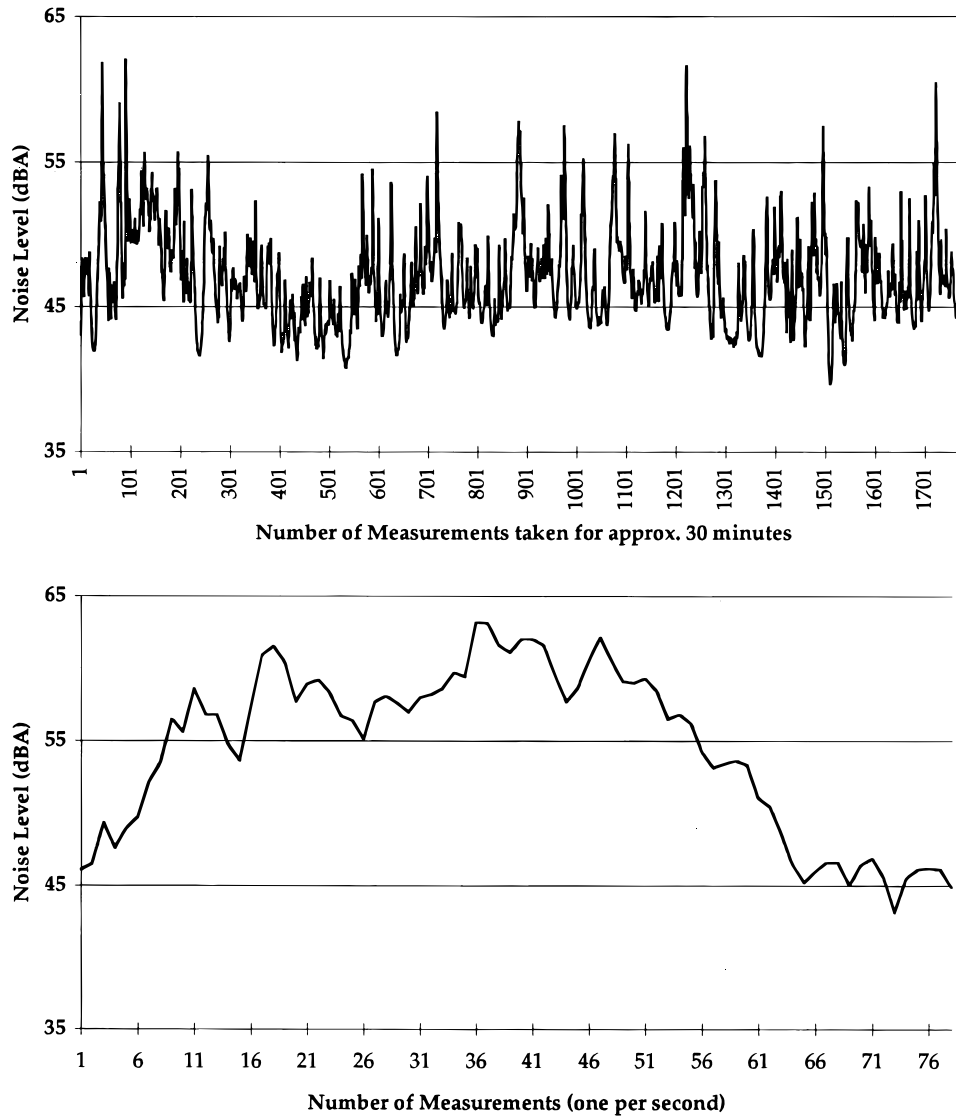


FIGURE 2 Kurtistown (Station 2) sample: (top) background noise profile and (bottom) helicopter noise profile.

town. The average ambient noise level at the specific location is slightly less than 50 dB (A). The bottom graph is a detailed noise profile of one helicopter overflight. The peak noise level for this flight was about 64 dB (A). Dozens of similar profiles were generated.

The data selected for analysis include only the helicopter overflights for which a clear measurement of helicopter noise was made (helicopter plus ambient noise level, to be exact); it excludes all cases where a noisy vehicle, strong wind gusts, and people or animal sounds interfered with the helicopter noise. Proper note-taking during the survey made such a screening possible.

There are more appropriate methods and equipment for noise measurement [i.e., day-night sound averages (DNL) taken near homes], but equipment and other resources made their use infeasible. As a result, the analysis presented here focuses more on frequency and duration of overflights (since the mea-

surements are, in all likelihood, unbiased and proper) and less on noise intensity.

Based on the half-hour profiles of ambient and traffic noise measurements at each station, a number of vehicle profiles (9 to 39, depending on availability) were selected for the estimation of traffic $L(\max)$ and $L(\text{mean})$. Single-vehicle passages were selected so that complex decompositions of overlapping noise profiles would be avoided. Then basic noise statistics were derived from the sample of vehicular noise profiles.

The ambient noise level, $L(\text{amb})$, the average traffic noise, $L(\text{mean})$, and the maximum traffic and helicopter noise, $L(\max)$, are plotted in Figure 3. The ambient noise level has been subtracted from the other noise indicators plotted; thus, the helicopter and traffic $L(\max)$ reflect the net noise level generated. The plot has been sorted in an ascending order for helicopter $L(\max)$, which is represented by the thick solid line.

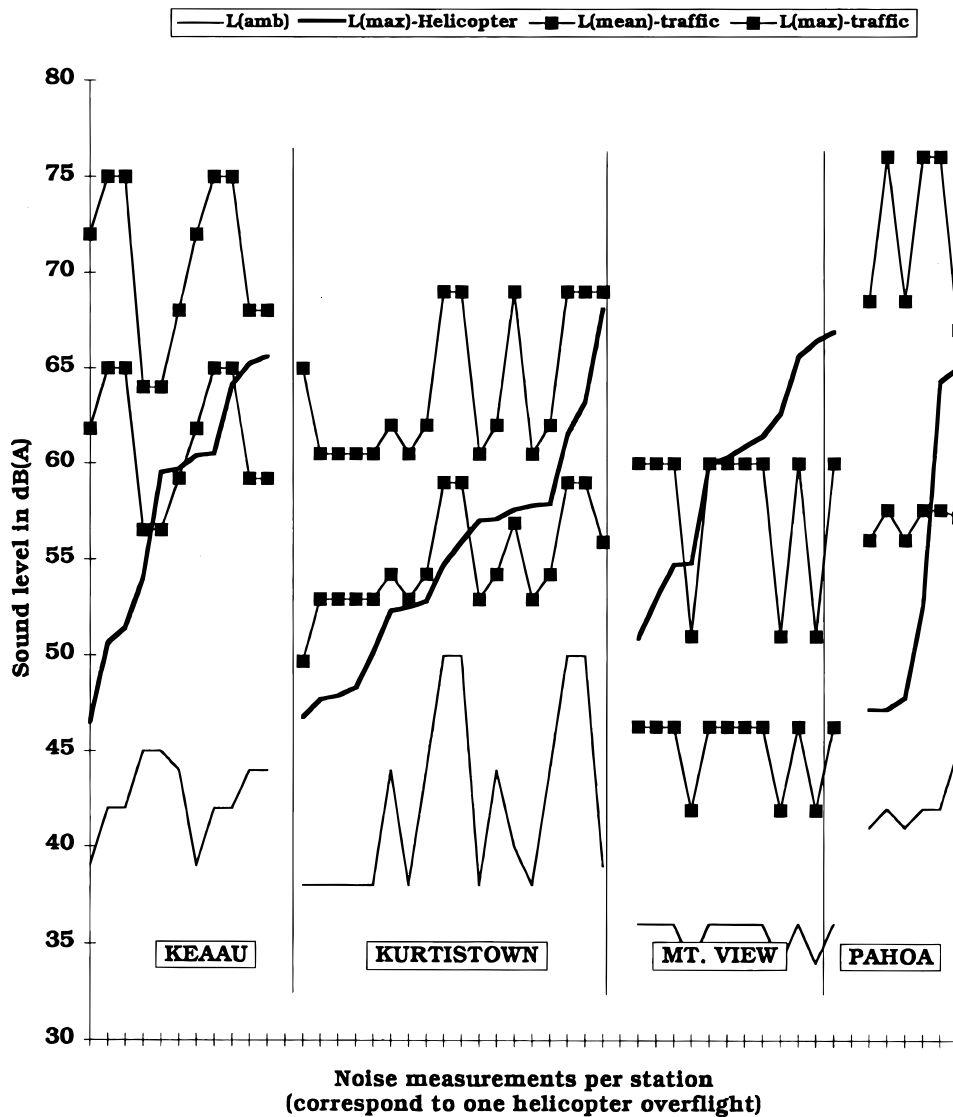


FIGURE 3 Helicopter, ambient, and vehicular traffic noise levels in four towns.

It is obvious that the helicopter noise level in all cases is clearly above the ambient noise level, and that in the majority of the cases it exceeds the mean traffic noise level. As expected, the helicopter noise level rarely exceeds the traffic $L(max)$, not only because several traffic maxima are due to noisy motorcycles or poorly maintained vehicles, but also because the distance of the noise equipment in the field was about 3 to 6 m (10 to 20 ft) away from major roadways, whereas most helicopters flew at a considerable altitude. (No attempt was made to record the distance and altitude of helicopter flights because they would be subjective and inaccurate since they are influenced by such factors as direction and speed of flight, size of helicopter, visibility conditions, etc.)

Notably, helicopter noise is most intrusive in Mountain View. This is because the station for the instruments was about 45 m (150 ft) away from the major roadway in the area. Thus, traffic $L(max)$ is much lower than at the other sites; consequent-

ly, the helicopter $L(max)$ exceeds the traffic $L(max)$ in most cases.

Table 2 summarizes the average frequency of helicopter overflights per hour. Day of the week, weather, and cruise ship arrivals affect tour helicopter flight frequency and cause an irregular pattern. For example, no helicopter operations took place during the 2.5 hr of observation at Keaau, Station 1, starting at 8:00 a.m. on a Saturday. But five overflights corresponding to an average frequency of about three overflights per hour were recorded at the same station and approximate time on a Monday. In some instances, nearly six overflights per hour took place at Kurtistown and Mountain View.

The averages for helicopter operational characteristics in the sampled communities are specified in Table 3, which also contains the respective samples of field measurements and questionnaire responses.

TABLE 2 Frequency of Helicopter Flights

| Location | Stn. | Day | Start Time | Duration of Meas. (min.) | Occurrences | Hourly Freq. |
|------------|------|-----|------------|--------------------------|-------------|--------------|
| Keaau | 1 | SA | 8:00 | 150 | 0 | 0.0 |
| | 2 | SA | 10:40 | 140 | 5 | 2.1 |
| | 3 | SA | 13:13 | 135 | 6 | 2.7 |
| | 1 | SA | 15:35 | 40 | 1 | 1.5 |
| | 1 | MO | 8:27 | 105 | 5 | 2.9 |
| | 2 | MO | 10:39 | 121 | 7 | 3.5 |
| | 3 | MO | 13:15 | 105 | 0 | 0.0 |
| | 1 | MO | 15:07 | 53 | 1 | 1.1 |
| Kurtistown | 1 | SU | 8:07 | 93 | 0 | 0.0 |
| | 2 | SU | 9:45 | 135 | 4 | 1.8 |
| | 3 | SU | 12:20 | 130 | 1 | 0.5 |
| | 4 | SU | 14:40 | 80 | 5 | 3.8 |
| | 1 | TU | 8:10 | 115 | 3 | 1.6 |
| | 2 | TU | 10:12 | 118 | 6 | 3.1 |
| | 3 | TU | 12:37 | 93 | 9 | 5.8 |
| | 4 | TU | 14:19 | 104 | 1 | 0.6 |
| Mt. View | 1 | TH | 8:00 | 120 | 1 | 0.5 |
| | 2 | TH | 10:14 | 111 | 11 | 5.9 |
| | 3 | TH | 12:13 | 107 | 2 | 1.1 |
| | 2 | TH | 14:06 | 114 | 10 | 5.3 |
| | 1 | SU | 8:00 | 122 | 1 | 0.5 |
| | 2 | SU | 10:09 | 114 | 3 | 1.6 |
| | 3 | SU | 12:10 | 112 | 3 | 1.6 |
| | 2 | SU | 14:07 | 116 | 5 | 2.6 |
| Pahoa | 1 | FR | 8:07 | 118 | 4 | 2.0 |
| | 2 | FR | 10:12 | 168 | 6 | 2.1 |
| | 3 | FR | 13:43 | 137 | 3 | 1.3 |
| | 1 | SA | 8:00 | 150 | 3 | 1.2 |
| | 2 | SA | 10:38 | 142 | 5 | 2.1 |
| | 3 | SA | 13:02 | 178 | 0 | 0.0 |

The frequency statistics presented in Table 3 were derived from the original field measurements, which are summarized in Table 2, by using a weighted average to yield the average weekly frequency based on (a) the weekday and weekend field observations, and (b) the duration of the field observations, as follows:

TABLE 3 Summary of Selected Characteristics

| Community | Frequency (overflights per day) | Duration (min /day) | Noise (μPa & dBA) | Questionnaire Responses (Perceptions) | Field Measures (Overflights) |
|------------|---------------------------------|---------------------|-------------------------|---------------------------------------|------------------------------|
| Keaau | 15 | 0.15 | 22,440 61.0 | 16 | 11 |
| Kurtistown | 18 | 0.36 | 17,419 58.8 | 48 | 18 |
| Mt. View | 16 | 0.24 | 26,063 62.3 | 31 | 12 |
| Pahoa | 10 | 0.07 | 20,231 60.1 | 90 | 6 |

$$X = [2 \cdot (8 \cdot F_{we}/t_{we}) + 5 \cdot (8 \cdot F_{wd}/t_{wd})]/7 \quad (2)$$

where

- X_1 = average daily frequency of helicopter operations,
- F_{we} = frequency of weekend operations (e.g., 12 for Keaau, Table 2),
- t_{we} = duration of weekend field measurements in hours (e.g., 7.75 for Keaau),
- F_{wd} = frequency of weekday operations (e.g., 13 for Keaau, Table 2), and
- t_{wd} = duration of weekday field measurements in hours (e.g., 6.4 for Keaau).

Substitution of the example numbers given in the description of Equation 2 for the community of Keaau in Equation 2 yields an average frequency of 15 overflights on a typical day, which is shown in Table 3. A similar calculation was performed to derive the average daily duration of overflights.

As stated earlier, the questionnaire survey and the field measurements were conducted independently. The averages of the helicopter operation characteristics listed above were coded into the questionnaire survey data based on the geographical (zip code) correspondence. In addition, the number of field measurements (last column in Table 3) was input to be used as weights in the subsequent modeling efforts. This was done because, conceivably, more measurements tend to translate to more reliable averages of the conditions over the boundaries of each community.

Linear and nonlinear regressions were estimated using SPSS/PC+ (and invoking the subcommand REGWGT in the REGRESSION procedure). The relationship between the independent variables of frequency (X_1) and duration (X_2) and the dependent variables Y_1 (helicopter noise annoyance at home) and Y_F (composite variable estimated according to Equation 1, including annoyance at home, and at work, fear of crashes, and sleep and privacy disturbances) were sought. The models are shown in Table 4 and Figure 4.

A nonlinear relationship fits frequency best, whereas a linear one is best for duration. Although the models display a mediocre overall fit to the data (based on the R^2 index), they are strongly statistically significant as evidenced by the t -statistic for each parameter estimate and the overall model F -score. In Figure 4, annoyance begins in the neighborhood of 1 ("annoyed"). Annoyance strictly from noise (Y_1 , solid line plot) is more bothersome than the composite factor annoyance (Y_F , dashed line plot). This outcome is correct since respondents have indicated lesser disturbance from noise at work or from fear of crashes, sleep deprivation, and invasion of privacy.

The model indicates that, on the average, some form of annoyance sets in at a frequency of overflights of about 10 or more per day. Given the methodology with which data were gathered, the model includes all flights that are audible at the point of reception. The findings are in accord with those in a study by the Rumson Corporation (1,2) in which about 8 overflights form the threshold beyond which annoyance increases exponentially and 25 overflights are deemed extremely annoying (rating of nearly 12 on a scale from 0 to 12). Indeed, our results indicate that 20 or more overflights are likely to cause people to respond as "very annoyed." Similar observations can be made for duration (bottom graph). Annoyance sets in after a total of about 10 min of audible helicopter overflights in a day.

Two new variables were created to separate the population sample into those who are likely to be highly annoyed (rating exceeding

TABLE 4 Models Connecting Helicopter Flight Characteristics with Annoyance

| MODEL | MODEL FIT STATISTICS |
|---|--|
| $Y_1 = -0.09 + 0.0053 X_1^2$ | $R^2 = 0.16$, $F = 33.9$, $t_1 = 14.6$ (99%), $t_X = 5.8$ (99%), $N = 158$ |
| $Y_F = -0.40 + 0.005 X_1^2$ | $R^2 = 0.16$, $F = 30.8$, $t_1 = 11.8$ (99%), $t_X = 5.5$ (99%), $N = 158$ |
| $\%HA_H = 0.203 + 0.00156 X_1^2$ | $R^2 = 0.09$, $F = 18.5$, $t_1 = 2.6$ (98%), $t_X = 4.3$ (99%), $N = 158$ |
| $\%HA_F = 0.107 + 0.00125 X_1^2$ | $R^2 = 0.06$, $F = 12.7$, $t_1 = 1.4$ (84%), $t_X = 3.6$ (99%), $N = 158$ |
| Duration of of flyovers (X_2) | |
| MODEL | MODEL FIT STATISTICS |
| $Y_1 = 0.21 + 4.083 X_2$ | $R^2 = 0.15$, $F = 31.1$, $t_1 = 20.1$ (99%), $t_X = 5.6$ (99%), $N = 184$ |
| $Y_F = -0.32 + 3.728 X_2$ | $R^2 = 0.15$, $F = 27.4$, $t_1 = 16.5$ (99%), $t_X = 5.2$ (99%), $N = 184$ |
| $\%HA_H = 0.298 + 1.162 X_2$ | $R^2 = 0.08$, $F = 16.1$, $t_1 = 4.7$ (99%), $t_X = 4.0$ (99%), $N = 184$ |
| $\%HA_F = 0.178 + 0.956 X_2$ | $R^2 = 0.06$, $F = 11.7$, $t_1 = 2.9$ (99%), $t_X = 3.4$ (99%), $N = 184$ |

Notes: All F-scores are statistically significant at the 99% level; t_1 = t-statistic for the intercept, t_X = t-statistic for the independent variable (both based on 2-tailed test); Y_1 , Y_F , $\%HA_H$ and $\%HA_F$ are defined in the text.

1 on the -2 to $+2$ scale) and those who are not. The variable “% highly annoyed” based on the Y_1 variable (noise annoyance at home) is $\%HA_H$, whereas $\%HA_F$ is based on the Y_F variable (composite annoyance). The models are shown in Table 4 and Figure 5; they display a mediocre to poor R^2 but they are strongly statistically significant. The models indicate that the majority of the population examined is likely to be highly annoyed by helicopter overflights when frequency exceeds 14 flights per day, or 18 flights per day, based on the composite index. The same reaction should be expected when the duration of audible overflights exceeds about 10 min (noise-based) or about 20 min (composite annoyance-based) per day.

CONCLUSIONS

The logical expectation that more exposure to helicopter overflights would cause more negative perceptions about helicopter operations has been substantiated. In proving a specific research hypothesis, it was shown that although helicopter flights on the island of Hawaii do not generate a remarkably high level of noise, their noise is clearly above the ambient and the mean traffic noise levels at locations near major roadways. The difference between helicopter and

ambient noise level should be greater at locations far from major roadways. More importantly, specific relationships between annoyance and helicopter operation characteristics, such as frequency and duration of overflights, were identified. Annoyance increased exponentially with increasing frequency of overflights, whereas it increases linearly with increasing total daily duration of audible overflights. The results are consistent with similar studies: Annoyance seems to set in when frequency exceeds about 10 overflights per day, and the operations become very annoying as they reach 20 overflights.

It may be argued that the nonsimultaneous measurement of perceptions and noise (as in studies in the vicinity of airports and military installations) may be problematic. This research approach may be more appropriate in semirural communities because people’s perceptions reflect long-time beliefs and do not carry the bias of a controlled experimental study. In addition, the field measurements covered a wide area; they were not restricted to a specific neighborhood, thus giving a more representative picture of the problems in a wide flight corridor. Finally, the field measurements were done without the knowledge of anybody involved in the issue (i.e., residents, helicopter operators, aviation officials, etc.). Thus, the field data, particularly frequency and duration, are likely to be unbiased and representative of the actual field conditions.

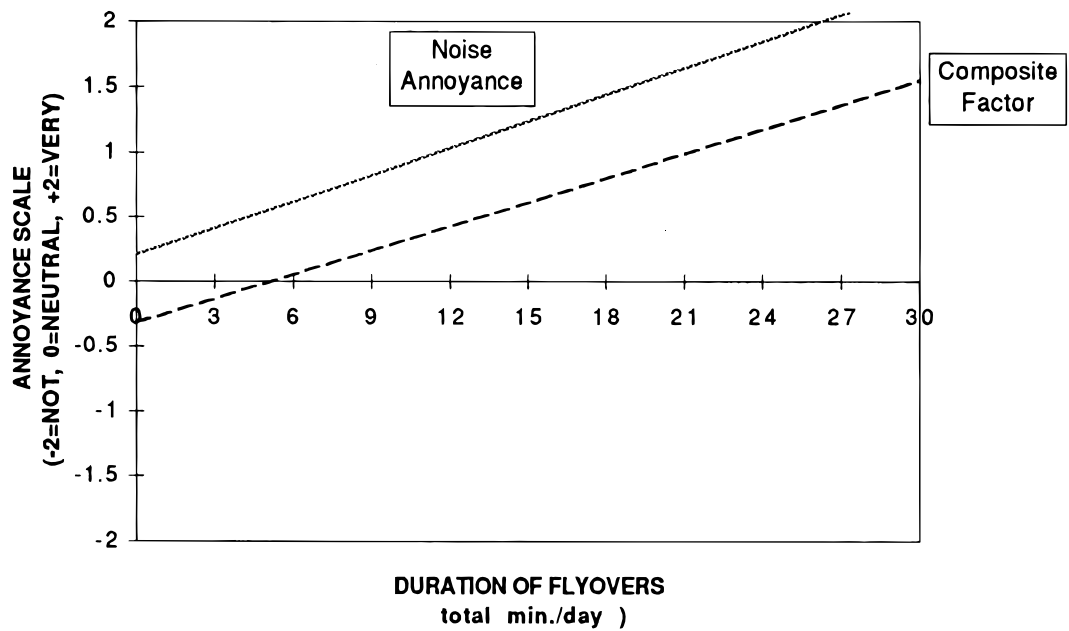
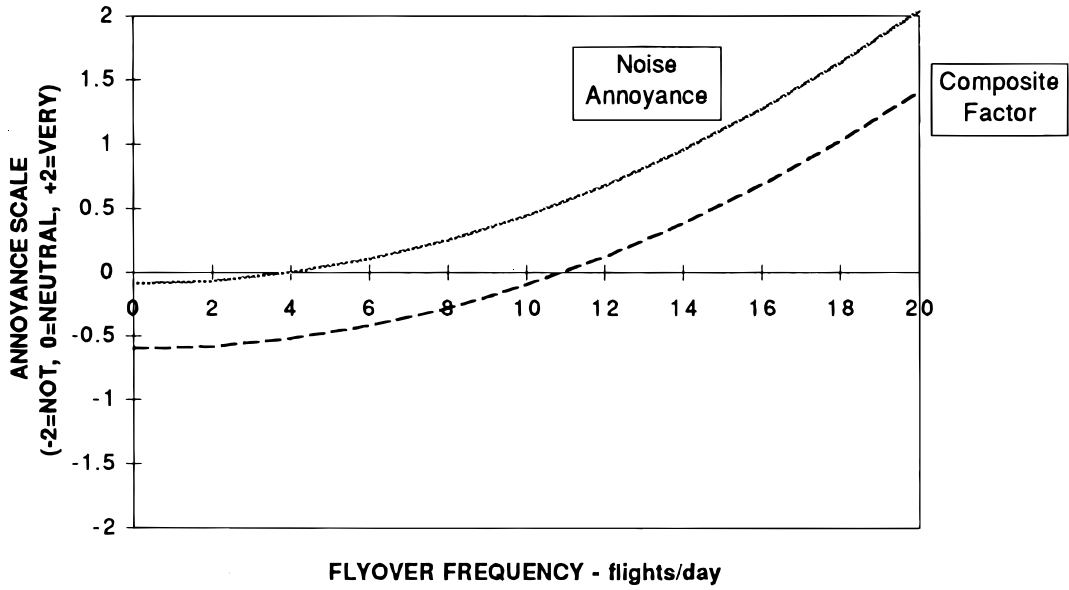


FIGURE 4 Effect on annoyance of (top) flyover frequency and (bottom) duration.

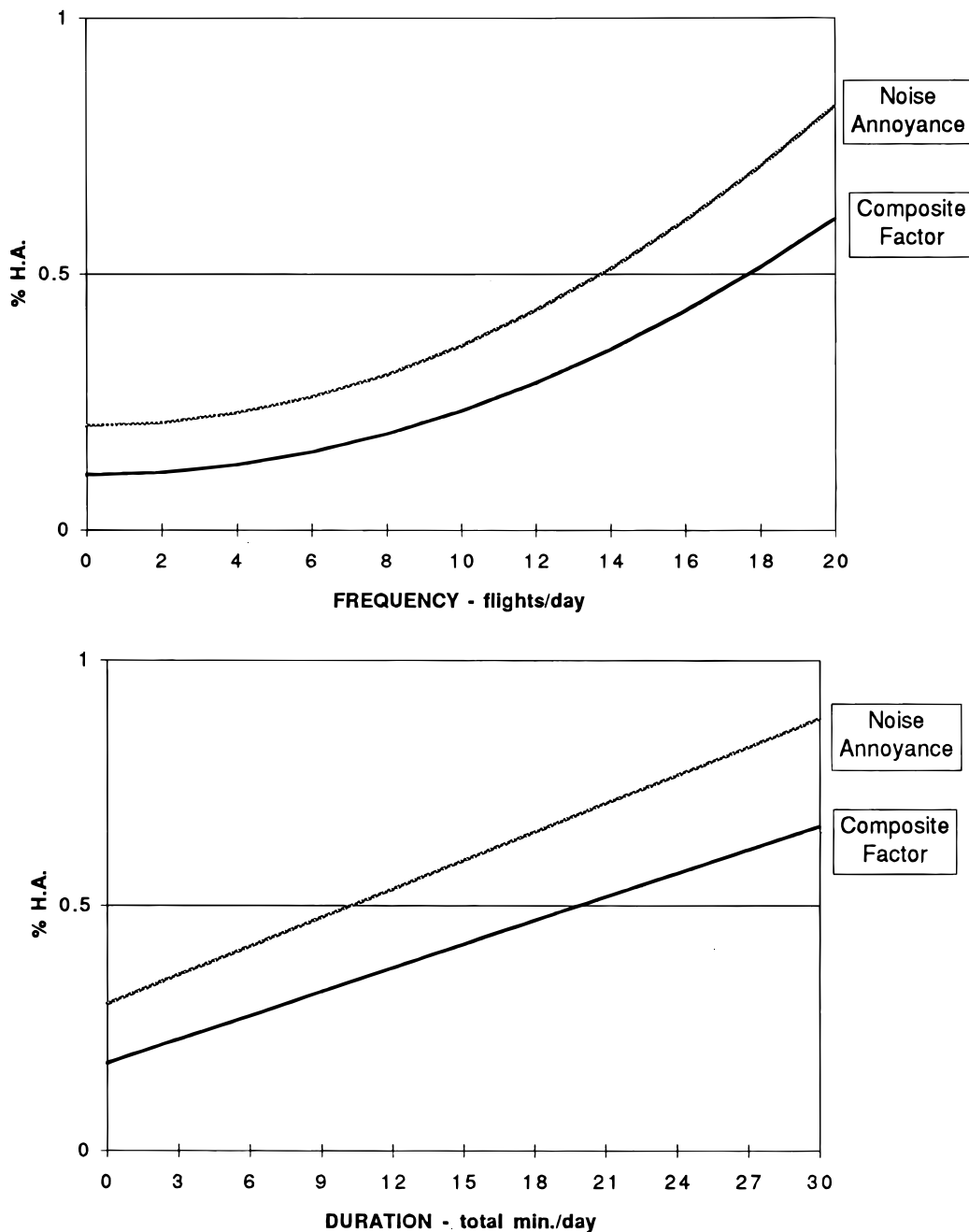


FIGURE 5 Effect on “% highly annoyed” of (top) flyover frequency and (bottom) flyover duration.

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