continuing, there is insufficient scientific evidence to support these concerns (Newman and Beattie 1985, pp. 59-62).

Taylor and Wilkins (1987, p. 4/10) offer the following conclusions in their review of the research.

The evidence of non-auditory effects of transportation noise is more ambiguous, leading to differences of opinion regarding the burden of prudence for noise control. There is no strong evidence that noise has a direct causal effect on such health outcomes as cardiovascular disease, reproductive abnormality, or psychiatric disorder. At the same time, the evidence is not strong enough to reject the hypothesis that noise is in some way involved in the multi-causal process leading to these disorders. But even with necessary improvements in study design, the inherent difficulty of isolating the effect of a low dose agent such as transportation noise within a complex aetiological system will remain. It seems unlikely, therefore, that research in the near future will yield findings which are definitive in either a positive or negative direction. Consequently, arguments for transportation noise control will probably continue to be based primarily on welfare criteria such as annoyance and activity disturbance.

Recent case studies on mental illness and hypertension indicate that this conclusion remains valid. Yoshida and Nakamura (1990) found that long-term exposure to sound pressure levels above 65 DNL may contribute to reported ill effects on mental well-being. This case study, however, concluded that more research is needed because the results also contained some contrary effects, indicating that in some circumstances, ill effects were negatively correlated with increasing noise.

Griefahn (1992) studied the impact of noise exposure ranging from 62 dBA to 80 dBA on people with hypertension. She found that there is a tendency for vasoconstriction to increase among untreated hypertensive people as noise level increases. However, she also found that beta blocking medication prevented any increase in vasoconstriction attributable to noise. She concluded that while noise may be related to the onset of hypertension, especially in the presence of other risk factors, hypertensive people do not run a higher risk of ill-health effects if they are properly treated.

**SLEEP DISTURBANCE**

There is a large body of research documenting the effect of noise on sleep disturbance, but the long-range effects of sleep disturbance caused by nighttime airport operations are not well understood. It is clear that sleep is essential for good physical and emotional health, and noise can interfere with sleep, even when the sleeper is not consciously awakened. While the long-term effect of sleep deprivation on mental and physical function is not clear, it is known to be harmful. It is also known that sleepers do not fully adjust to noise disruption over time. Although they may awaken less often and have fewer conscious memories of disturbance, noise-induced shifts in sleep levels continue to occur.
Reviews of the laboratory research on sleep disturbance report that the level of noise which can cause awakenings or interfere with falling asleep ranges from 35 dBA to 80 dBA depending on the sleep stage and variability among individuals (Newman and Beattie 1985, pp. 51-58; Kryter 1984, pp. 422-431). There is evidence that older people tend to be much more sensitive to noise-induced awakenings than younger people. Research has shown that, when measured through awakenings, people tend to become somewhat accustomed to noise. On the other hand, electroencephalograms, which reveal information about sleep stages, show little habituation to noise. Kryter describes these responses to noise as "alerting responses." He suggests that because they occur unconsciously, they may simply be reflexive responses, reflecting normal physiological functions which are probably not a cause of stress to the organism.

Most studies of sleep disturbance have been conducted under controlled laboratory conditions. The laboratory studies do not allow generalizations about the potential for sleep disturbance in an actual airport setting, and more importantly, the impact of these disturbances on the residents. Furthermore, the range of sound levels required to cause sleep disturbance, ranging from a whisper to a shout (35 dB to 80 dB), and the prevalence of sleep disruption in the absence of any noise, greatly complicates the making of reasonable generalizations about the effect of noise on sleep.

Fortunately, some studies have examined the effect of nighttime noise on sleep disturbance in actual community settings. One report summarizes the results of eight studies conducted in homes (Fields 1986). Four studies examined aircraft noise, the others highway noise. In all of them, sleep disturbance was correlated with cumulative noise exposure metrics such as Leq and L10. All studies showed a distinct tendency for increased sleep disturbance as cumulative noise exposure increased. The reviewer notes, however, that sleep disturbance was very common, regardless of noise levels, and that many factors contributed to it. He points out that, "the prevalence of sleep disturbance in the absence of noise means that considerable caution must be exercised in interpreting any reports of sleep disturbance in noisy areas."

A review of the literature, Pearsons, et al. (1990), compared the data and findings of laboratory and field studies conducted in the homes of subjects. They found that noise-induced awakenings in the home were much less prevalent than in the laboratory. They also found that much higher noise levels were required to induce awakenings in the home than in the laboratory. Exhibit A compares the percentage of people awakened at different sound levels in laboratory and field studies. The graph clearly shows a marked tendency for people in laboratory settings to be much more sensitive to noise than if their homes. The reason for the large difference is apparently that people in their
Effects Exhibit A

COMPARISON OF A WAKENING DUE TO NOISE EVENTS FROM LABORATORY VERSUS FIELD STUDIES

homes are fully habituated to their environment, including the noise levels.

Finegold et al. (1994) reviewed the data in the Pearsons report of 1990 and developed a regression analysis. As shown in Exhibit B, an exponential curve was found to fit the categorized data reasonably well. They recommend that this curve be used as a provisional means of predicting potential sleep disturbance from aircraft noise. They caution that because the curve was derived using Pearsons' laboratory, as well as in-home, data, the predictions of sleep disruption in an actual community setting derived from this curve are likely to be high.

The findings of many of these sleep disturbance studies, while helping to answer basic research questions, are of little usefulness to policy makers and airport residents. For them, the important question is, "When does sleep disturbance caused by environmental noise become severe enough to constitute a problem in the community?" Kryter (1984, pp. 434-443) reviews in detail one important study that sheds light on this question. The Directorate of Operational Research and Analysis (DORA) of the British Civil Aviation Authority conducted an in-depth survey of 4,400 residents near London's Heathrow and Gatwick Airports over a four-month period in 1979 (DORA 1980). The study was intended to answer two policy-related questions: "What is the level of aircraft noise which will disturb a sleeping person?" and "What level of aircraft noise prevents people from getting to sleep?"

Analysis of the survey results indicated that the best correlations were found using cumulative energy dosage metrics, namely Leq. Kryter notes that support for the use of the Leq metric is provided by the finding that some respondents could not accurately recall the time association of a specific flight with an arousal from sleep. This suggests that the noise from successive overflights increased the general state of arousability from sleep.

With regard to difficulty in getting to sleep, the study found 25 percent of the respondents reporting this problem at noise levels of 60 Leq, 33 percent at 65 Leq, and 42 percent at 70 Leq. The percentage of people who reported being awakened at least once per week by aircraft noise was 19 percent at 50 Leq, 24 percent at 55 Leq, and 28 percent at 60 Leq. The percentage of people bothered "very much" or "quite a lot" by aircraft noise at night when in bed was 22 percent at 55 Leq and 30 percent at 60 Leq. Extrapolation of the trend line would put the percentage reporting annoyance at 65 Leq well above 40 percent.

DORA concluded with the following answers to the policy-related questions: (1) A significant increase in reports of sleep arousal will occur at noise levels at or above 65 Leq; (2) A significant increase in the number of people reporting difficulty in getting to sleep will occur at noise levels at or above 70 Leq. Kryter disagrees with these findings. He believes that a more careful reflection upon the data leads to the conclusion that noise levels
approximately 10 decibels lower would represent the appropriate thresholds -- 55 and 60 Leq.

At any airport, the 65 DNL contour developed from total daily aircraft activity will be larger than the 55 Leq developed from nighttime activity only. (At an airport with only nighttime use, the 65 DNL contour will be identical with the 55 Leq contour because of the effect of the 10 dB penalty in the DNL metric.) Thus, the 65 DNL contour defines a noise impact envelope which encompasses all of the area within which significant sleep disturbance may be expected based on Kryter's interpretation of the DORA findings discussed above.

Another study was conducted by the British Civil Aviation Authority to examine the relationship of nighttime aircraft noise and sleep disturbance near four major airports -- Heathrow, Gatwick, Stansted, and Manchester (Ollerhead, et al. 1992). A total of 400 subjects were monitored for a total of 5,742 subject-nights. Nightly awakenings were found to be very common as part of natural sleep patterns. Researchers found that for aircraft noise events below 90 SEL, as measured outdoors, there was likely to be no measurable increase in rates of sleep disturbance. (The indoor level can be roughly estimated as approximately 20 to 25 decibels less than the outdoor level.) Where noise events ranged from 90 to 100 SEL, a very small rate of increase in disturbance was possible. Overall rates of sleep disturbance were found to be more closely correlated with sleep stage than with periods of peak aircraft activity. That is, sleep was more likely to be disrupted, from any cause, during light stages than during heavy stages.

Exhibit C shows the relationship between arousal from sleep and outdoor sound exposure levels (SELs) found in the 1992 British study. The results have been statistically adjusted to control for the effects of individual variability in sleep disturbance. The study found that the arousal rate for the average person, with no aircraft noise, was 5.1 percent. Aircraft noise of less than SEL 90 dBA was found not to be statistically significant as a cause of sleep disturbance. (According to the study, this would correspond to an Lmax of approximately 81 dBA. Lmax is the loudest sound the human ear would actually hear during the 90 SEL noise event. The interior Lmax would be approximately 20 to 25 decibels less -- roughly 56 to 61 dBA.) The 95 percent prediction interval is shown on the graph not to rise above the 5.1 percent base arousal rate until it is above 90 dBA. Again, it should be emphasized that these conclusions relate to the average person. More easily aroused people will be disturbed at lower noise levels, but they are also more likely to be aroused from other sources (Ollerhead, et al. 1992).

**STRUCTURAL DAMAGE**

Structural vibration from aircraft noise in the low frequency ranges is sometimes a concern of airport neighbors. While vibration contributes to annoyance reported by
\[
\% \text{ Awakenings} = 0.0000071 \times L_{AE}^{3.5}
\]

**LEGEND**

- Observed
- Predicted

**Note:** Based on laboratory and field data reported in Pearsons et al. 1989.

**Source:** Finegold et al. 1994.
Note: Estimates controlled for the effects of individual arousability

residents near airports, especially when it is accompanied by high audible sound levels, it rarely carries enough energy to damage safely constructed structures. High-impulse sounds such as blasting, sonic booms, and artillery fire are more likely to cause damage than continuous sounds such as aircraft noise. A document published by the National Academy of Sciences suggested that one may conservatively consider noise levels above 130 dB lasting more than one second as potentially damaging to structures (CHABA 1977). Aircraft noise of this magnitude occurs on the ramp and runway and seldom, if ever, occurs beyond the boundaries of a commercial or general aviation airport.

The risk of structural damage from aircraft noise was studied as part of the environmental assessment of the Concorde supersonic jet transport. The probability of damage from Concorde overflights was found to be extremely slight. Actual overflight noise from the Concorde at Sully Plantation near Dulles International Airport in Fairfax County, Virginia was recorded at 115 dBA. No damage to the historic structures was found, despite their age. Since the Concorde causes significantly more vibration than conventional commercial jet aircraft, the risk of structural damage caused by aircraft noise near airports is considered to be negligible (Hershey et al. 1975; Wiggins 1975).

OTHER ANNOYANCES

The psychological impact of aircraft noise is a more serious concern than direct physical impact. Studies conducted in the late 1960s and early 1970s found that the interruption of communication, rest, relaxation, and sleep are important causes for complaints about aircraft noise. Disturbance of television viewing, radio listening, and telephone conversations are also sources of serious annoyance.

Exhibit D shows the relationship between sound levels and communicating distance for different voice levels. Assuming a communicating distance of 2 meters, communication becomes unsatisfactory with a steady noise level above about 65 decibels. At 65 decibels, a raised voice is required to maintain satisfactory conversation. Another way to interpret this is that a raised voice would be interrupted by a sound event above 65 decibels. A normal voice would be interrupted, at two meters, by a sound event of 60 decibels.

Exhibit E shows the impact of aircraft noise on conversation and radio or television listening. These results, summarized by Schultz (1978), were derived from surveys conducted in London, France, Munich, and Switzerland. Differences in the amount of disturbance reported in each study are based on how each survey defined disturbance. The British study counted mild disturbance, the French moderate disturbance, and the German and Swiss great disturbance.

In the case of conversation disruption, nine percent were greatly annoyed by noise of 60 DNL in the Swiss study. About 12 to
16 percent of those in the Swiss and German studies considered themselves to be greatly disturbed by aircraft noise of 65 DNL. At 75 DNL, 40 to 50 percent considered themselves greatly disturbed. In the French study, 23 percent considered themselves moderately disturbed by aircraft noise at 60 DNL, 35 percent at 65 DNL, and 75 percent at 75 DNL. In the British study, 37 percent were mildly disturbed by aircraft noise at 60 DNL, 50 percent at 65 DNL, and about 72 percent at 75 DNL.

Regarding interference with television and radio listening, about 13 percent in the Swiss study were greatly disturbed by aircraft noise above 60 DNL, 21 percent at 65 DNL, and 40 percent at 75 DNL. In the British and French studies, 42 to 45 percent were mildly to moderately disturbed by noise at 60 DNL, 55 percent at 65 DNL, and 75 to 82 percent at 75 DNL.

In some cases, noise is only an indirect indicator of the real concern of airport neighbors -- safety. The sound of approaching aircraft may cause fear in some people about the possibility of a crash. This fear is a factor motivating some complaints of annoyance in neighborhoods near airports around the country. (See Richards and Ollerhead 1973; FAA 1977; Kryter 1984, p. 533.) This effect tends to be most pronounced in areas directly beneath frequently used flight tracks (Gjestland 1989).

The EPA has also found that continuous exposure to high noise levels can affect work performance, especially in high-stress occupations. Based on the FAA's land use compatibility guidelines, discussed in the Technical Information Paper on Noise and Land Use Compatibility, these adverse affects are most likely to occur within the 75 DNL contour.

Individual human response to noise is highly variable and is influenced by many factors. These include emotional variables, feelings about the necessity or preventability of the noise, judgments about the value of the activity creating the noise, an individual's activity at the time the noise is heard, general sensitivity to noise, beliefs about the impact of noise on health, and feelings of fear associated with the noise. Physical factors influencing an individual's reaction to noise include the background noise in the community, the time of day, the season of the year, the predictability of the noise, and the individual's control over the noise source.

**AVERAGE COMMUNITY RESPONSE TO NOISE**

Although individual responses to noise can vary greatly, the average response among a group of people is much less variable. This enables us to generalize about the average impacts of aircraft noise on a community despite the wide variations in individual response.

Many studies have examined average residential community response to noise, focusing on the relationship between annoyance and noise exposure.
Communicating Distance (Meters)

MAXIMUM DISTANCES OUTDOORS OVER WHICH CONVERSATION IS SATISFACTORILY INTELLIGIBLE IN STEADY NOISE

NOTE:

Differences in amount of interference reported are related to how individual surveys defined interference. London counted mild disturbance, France moderate disturbance, and Munich and Switzerland great disturbance.

(See DORA 1980; Fidell et al. 1989; Finegold et al. 1992 and 1994; Great Britain Committee on the Problem of Noise 1963; Kryter 1970; Richards and Ollerhead 1973; Schultz 1978; U.S. EPA 1974.) These studies have produced similar results, finding that annoyance is most directly related to cumulative noise exposure, rather than single-event exposure.

Annoyance has been found to increase along an S-shaped or logistic curve as cumulative noise exposure increases, as shown in Exhibit F. Developed by Finegold et al. (1992 and 1994), it is based on data derived from a number of studies of transportation noise (Fidell 1989). It shows the relationship between DNL levels and the percentage of people who are highly annoyed. Known as the "updated Schultz Curve", because it is based on the work of Schultz (1978), it represents the best available source of data for the noise dosage-response relationship (FICON 1992, Vol. 2, pp. 3-5; Finegold et al. 1994, pp. 26-27).

The updated Schultz Curve shows that annoyance is measurable beginning at 45 DNL, where 0.8 percent of people are highly annoyed. It increases gradually to 6.1 percent at 60 DNL. Starting at 65 DNL, the percentage of people expected to be highly annoyed increases steeply from 11.6 percent up to 68.4 percent at 85 DNL. Note that this relationship includes only those reported to be "highly annoyed". Based on other research, the percentages would be considerably higher if they also included those who were "moderately or mildly annoyed" (Richards and Ollerhead 1973; Schultz 1978).

**SUMMARY**

The effects of noise on people include hearing loss, other ill health effects, and annoyance. While harm to physical health is generally not a problem in neighborhoods near airports, annoyance is a common problem. Annoyance is caused by sleep disruption, interruption of conversations, interference with radio and television listening, and disturbance of quiet relaxation.

Individual responses to noise are highly variable, making it very difficult to predict how any person is likely to react to environmental noise. The average response among a large group of people, however, is much less variable and has been found to correlate well with cumulative noise dosage metrics such as Leq, DNL, and CNEL. The development of aircraft noise impact analysis techniques has been based on this relationship between average community response and cumulative noise exposure.
References


PERCENT HIGHERLY ANNOYED AT SELECTED NOISE LEVELS

<table>
<thead>
<tr>
<th>DNL</th>
<th>45</th>
<th>50</th>
<th>55</th>
<th>60</th>
<th>65</th>
<th>70</th>
<th>75</th>
<th>80</th>
<th>85</th>
<th>90</th>
</tr>
</thead>
<tbody>
<tr>
<td>%HA</td>
<td>0.8%</td>
<td>1.6%</td>
<td>3.1%</td>
<td>6.1%</td>
<td>11.6%</td>
<td>20.9%</td>
<td>34.8%</td>
<td>51.7%</td>
<td>68.4%</td>
<td>81.3%</td>
</tr>
</tbody>
</table>

Equation for Curve: \( \% \text{HA} = \frac{100}{1 + e^{(11.13 - .14 Ldn)}} \)


TECHNICAL INFORMATION PAPER

MEASURING THE IMPACT OF NOISE ON PEOPLE
In aircraft noise analysis, the effect of noise on residents near airports is often the most important concern. While certain public institutions and, at very high noise levels, some types of businesses may also be disturbed by noise, people in their homes are typically the most vulnerable to noise problems.

The most common way to measure the impact of noise on residents is to estimate the number of people residing within the noise contours. This is done by overlaying noise contours on census block maps or on maps of dwelling units. The number of people within each 5 DNL range (e.g. from 65 to 70 DNL, from 70 to 75 DNL, etc.) is then estimated.

This is the approach required in F.A.R. Part 150 noise compatibility studies. While it has the advantage of simplicity, it has one disadvantage: it implicitly assumes that all people are equally affected by noise, regardless of the noise level they experience. Clearly, however, the louder the noise, the greater the noise problem. As noise increases, more people become concerned about it, and the concerns of each individual become more serious.

**AVERAGE COMMUNITY RESPONSE TO NOISE**

Individual human response to noise is highly variable and is influenced by many factors. These include emotional variables, feelings about the necessity or preventability of the noise, judgments about the value of the activity creating the noise, an individual’s activity at the time the noise is heard, general sensitivity to noise, beliefs about the impact of noise on health, and feelings of fear associated with the noise.
Physical factors influencing an individual’s reaction to noise include the background noise in the community, the time of day, the season of the year, the predictability of the noise, and the individual’s control over the noise source.

Although individual responses to noise can vary greatly, the average response among a group of people is much less variable. This enables us to generalize about the average impacts of aircraft noise on a community despite the wide variations in individual response.

Many studies have examined average community response to noise, focusing on the relationship between annoyance and noise exposure. (See DORA 1980; Fidell et al. 1989; Finegold et al. 1992 and 1994; Great Britain Committee on the Problem of Noise 1963; Kryter 1970; Richards and Ollerhead 1973; Schultz 1978; U.S. EPA 1974.) These studies have produced similar results, finding that annoyance is most directly related to cumulative noise exposure, rather than single-event exposure.

Annoyance has been found to increase along an S-shaped or logistic curve as cumulative noise exposure increases, as shown in Exhibit A. This graph shows the percentage of residents either somewhat or seriously annoyed by noise of varying DNL levels. It was developed from research in the early 1970s (Richards and Ollerhead 1973). It is interesting that the graph indicates that at even extremely low noise levels, below 45 DNL, a very small percentage of people remain annoyed by aircraft noise. Conversely, the graph shows that while the percentage of people annoyed by noise exceeds 95 percent at 75 DNL, it only approaches, and does not reach, 100 percent even at the extremely high noise level of 85 DNL.

Exhibit A
ANNOYANCE CAUSED BY AIRCRAFT NOISE IN RESIDENTIAL AREAS
A similar graph is shown in Exhibit B. Developed by Finegold et al. (1992 and 1994), it is based on data derived from a number of studies of transportation noise (Fidell 1989). It shows the relationship between DNL levels and the percentage of people who are highly annoyed. Known as the "updated Schultz Curve", because it is based on the work of Schultz (1978), it represents the best available source of data for the noise dosage-response relationship (FICON 1992, Vol. 2, pp. 3-5; Finegold et al. 1994, pp. 26-27).

The updated Schultz Curve shows that annoyance is measurable beginning at 45 DNL, where 0.8 percent of people are highly annoyed. It increases gradually to 6.1 percent at 60 DNL. Starting at 65 DNL, the percentage of people expected to be highly annoyed increases steeply from 11.6 percent up to 68.4 percent at 85 DNL. Note that this relationship includes only those reported to be "highly annoyed". Based on the findings shown in Exhibit A, the percentages would be considerably higher if they also included those who were "moderately annoyed".

**THE DEVELOPMENT OF WEIGHTING FUNCTIONS**

Recognizing the tendency of annoyance response rates to increase systematically as noise increases, researchers in the 1960s began developing weighting functions to help estimate the total impact of noise on a population (CHABA 1977, p. B-1). The population impacted by noise at a given level would be multiplied by the appropriate weighting function. The higher the noise level, the higher the weighting function. The results for all noise levels would be added together. The sum would be a single number purported to represent the net impact of noise on the affected population.

The CHABA report (p. VII-5) recommended the use of the original Schultz curve as the basis for developing weighting functions. It recommended that weighting functions be developed by calculating the percentage of people likely to be highly annoyed by noise at various DNL levels. These values were then converted to weighting functions by arbitrarily setting the function for 75 DNL at 1.00. Functions for the other noise levels were set in proportion to the percent highly annoyed. The results of applying these weighting functions to a population was known as the "sound level weighted population" impacted by noise, or the "level-weighted population".

**UPDATED LEVEL-WEIGHTED POPULATION FUNCTIONS**

As discussed above, the original Schultz curve has been updated to take into account additional studies of community response to noise. The updated curve is shown in Exhibit B. Coffman Associates has updated the weighting functions developed by CHABA (1977, p. B-7) to correspond with the updated Schultz curve. Table 1 shows the percentage of people likely to be highly annoyed by aircraft noise for 5 DNL increments ranging from 45 to 80 DNL. It also shows weighting functions for use in calculating level-weighted population. These were developed by setting the
function for the 75 to 80 DNL range at unity (1.000). The other functions were computed in proportion to the values for "percent highly annoyed".

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Percent Highly Annoyed and Weighting Function by DNL Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNL Range</td>
<td>Average Percent</td>
</tr>
<tr>
<td>45-50</td>
<td>1.19%</td>
</tr>
<tr>
<td>50-55</td>
<td>2.36%</td>
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<tr>
<td>55-60</td>
<td>4.63%</td>
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<td>60-65</td>
<td>8.87%</td>
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<td>65-70</td>
<td>16.26%</td>
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<td>70-75</td>
<td>27.83%</td>
</tr>
<tr>
<td>75-80</td>
<td>43.25%</td>
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</tbody>
</table>

Based on the response curve shown in Exhibit A, the weighting functions can be considered as roughly equivalent to the proportion of people likely to be either highly annoyed or somewhat annoyed by noise.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Level-Weighted Population Methodology - Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNL Range</td>
<td>LWP Factor</td>
</tr>
<tr>
<td>65-70</td>
<td>.376</td>
</tr>
<tr>
<td>70-75</td>
<td>.644</td>
</tr>
<tr>
<td>75+</td>
<td>1.000</td>
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<tr>
<td>Total</td>
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**SUMMARY**

The response to noise among a group of people varies systematically with changes in noise levels. As noise increases, the proportion of people disturbed by noise increases. This relationship has been estimated and is presented in the "updated Schultz curve" shown in Exhibit B.

**EXAMPLE USE OF LEVEL-WEIGHTED POPULATION**

In airport noise compatibility planning, the level-weighted population (LWP) methodology is particularly useful in comparing the results of different noise analysis scenarios. Since the percentage of people who are highly annoyed increases with increasing noise levels, the LWP values may differ between operating scenarios even though the total population within the noise impact boundary is equal.

An example below illustrates the LWP methodology. Scenarios A and B show the effects of two airport operating scenarios. While the population subject to noise above 65 DNL is the same for both, Scenario B has a lower LWP because fewer people are impacted by the higher noise levels.

The data in the updated Schultz curve can be used to develop weighting functions for computing the numbers of people likely to be annoyed with noise. This is especially useful in comparing the net impact of different noise scenarios.

LWP TIP-4
Equation for Curve: \[ \% \text{HA} = \frac{100}{1 + e^{(11.13 - .14 \text{Ldn})}} \]


### PERCENT HIGHLY ANNOYED AT SELECTED NOISE LEVELS

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