Appendix **B**

Learning More About: Describing and Evaluating Airport Noise Impacts

Measuring Airport Noise

Measurement of Sound

Regardless of whether particular sounds are pleasant to hear or represent annoying or disruptive noise, their physical properties are measured in terms of three basic components: magnitude, frequency, and duration.

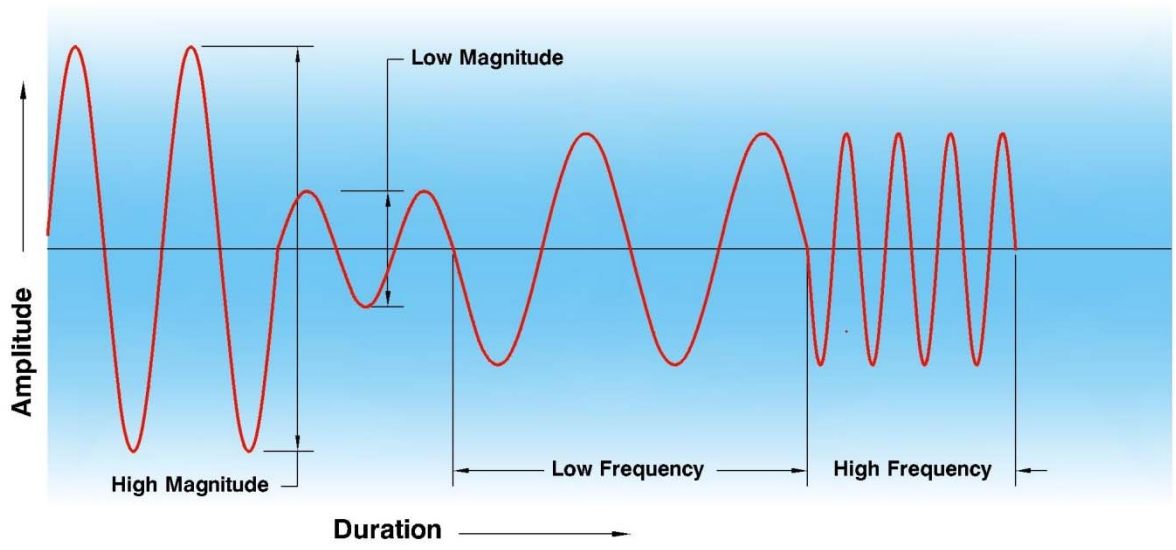
Sound is transmitted through the air when the movement of an object displaces the adjacent air particles which then bump into the next particles and so on. These actions form sets of pressure waves that strike our eardrums, causing them to vibrate and the sound to be heard.

- **Magnitude.** Magnitude is a measure of the strength or amount of acoustic energy carried by a sound wave. Because the energy level of sounds we can hear varies in magnitude by a factor of 1 to 100 trillion—that is 10^{14} or 1 followed by 14 zeros—we measure magnitude using a logarithmic scale rather than a linear one. Each step in this scale from 0 to 14 is referred to as one *bel* in honor of Alexander Graham Bell. More commonly, each bel is divided into tenths, thus the term *decibel* which is abbreviated as *dB*.

  Magnitude is related to loudness, but isn't the same. Loudness describes how we perceive sounds. We perceive any sound level increase of 10 dB (1 bel) as representing a doubling of loudness regardless of whether the increase is from 40 to 50 dB or from 80 to 90 dB. In each case, though, the acoustic energy or magnitude of the sound is actually increasing by a factor of 10.

- **Frequency.** Frequency describes the spacing between sound pressure waves. We hear differences in frequency as *tone*—a low-pitched tone has a long spacing or wavelength and a high-pitched done has a short wavelength. Measured relative to the number of cycles per second, the scale used is called *hertz* , abbreviated *Hz*. Most sounds do not consist of a single frequency—a pure tone—but are instead comprised of a mixture of different frequencies, each usually having its own magnitude.

  We don't hear all sound frequencies equally well. To balance what we perceive to be equally loud sounds of different frequencies, the measurement of sound magnitude is usually adjusted or weighted using A-weighted decibels expressed as dBA.



Noise Waves

- **Duration.** The final component is the time period over which a sound occurs. Measuring the duration of a sound is not always as simple as it would seem, however. Many sounds, such as those from an aircraft overflight begin softly, increase to a maximum magnitude, then drop away. Where we begin and end the measurement depends on what we can hear. Moreover, what we can hear often depends on the background or *ambient* sound level. Thus, a sound that barely reaches above the background level may seem to have a short duration, but in a quieter environment, we may find its duration to be much longer. In effect, a high background noise level masks much of the noise from individual aircraft overflights.

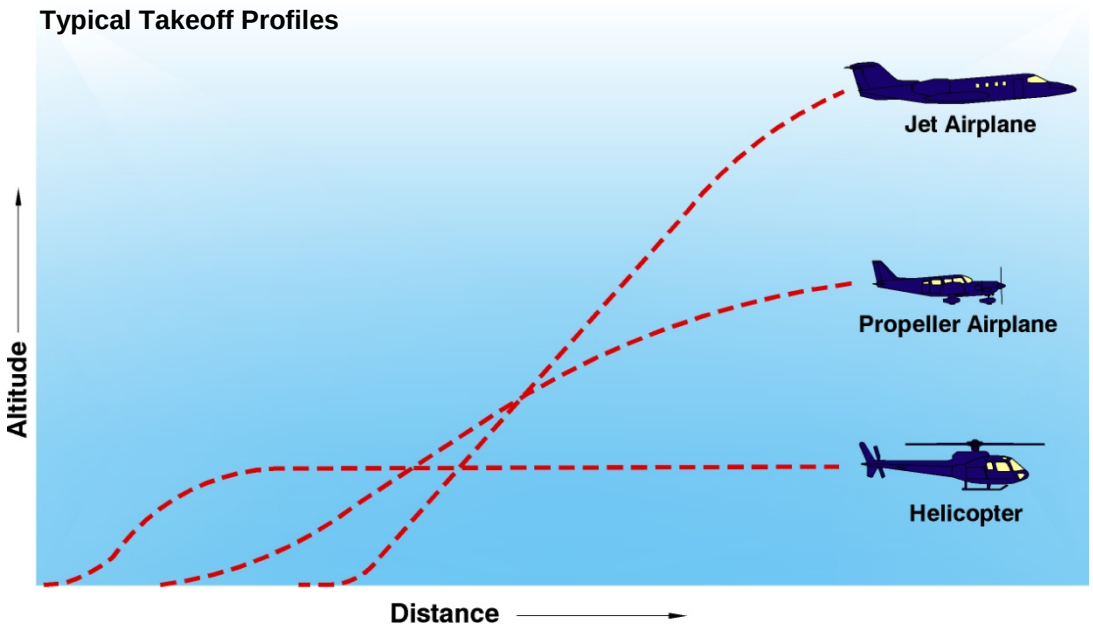
Noise Variations among Aircraft Types

Different types of aircraft sound differently. The magnitude, frequency, and duration of the sounds they create all differ. Moreover, variations occur not just among different types of aircraft, but even among different overflights of the same type of aircraft. The way the pilot flies the aircraft makes a difference.

- **Jet Airplanes.** The noise from jet airplanes was once distinct from other aircraft both by being louder and because it had a high pitch that was particularly annoying. Technology has enabled today's jets to be much quieter than their predecessors and the frequency is lower. Pound for pound, modern jets are quieter than equivalent propeller airplanes. However, on average, jets are larger than propeller planes and thus are typically noisier. Research is continuing into making jets still quieter, but there are tradeoffs between noise levels, fuel efficiency, and the amount of emissions produced.
- **Propeller Airplanes.** The dominant noise from propeller airplanes, whether driven by piston or turbine engines, is from the propeller itself. Unlike jet aircraft, the noise levels produced by propeller airplanes has changed very little over the years. Moreover, the potential for future technology to enable significant noise reduction is limited. Also, private airplanes such as found at general aviation airports are not replaced by newer models at anywhere near the rate common to airline aircraft. In all, no major changes in propeller airplane noise can be anticipated.

- **Helicopters.** Helicopter noise has unique characteristics. The relatively slow turning main rotor produces an impulsive sound that is particularly noticeable as the helicopter is approaching the listener. The noise is greatest during high-speed cruise and low-speed descents.

The amount of noise generated by different aircraft types is only one factor affecting how much noise is heard on the ground. Atmospheric conditions such as cloud cover that can make the sound bounce back to the ground can affect the noise levels that people hear. Another key factor is the altitude at which the aircraft are flying. In locations close to runways, the distinct performance capabilities of the different aircraft types greatly influences the noise impacts. As the illustration below shows, jets usually need more runway length to take off than propeller planes need, but then they climb much faster. At some point within a couple of miles of the runway end, jets will have reached a higher altitude than the more slow climbing propeller planes and their noise level on the ground will diminish more rapidly as they continue to climb more steeply. Helicopters don't need a runway to get airborne and they climb more steeply than airplanes (although they don't go straight up as is sometimes believed). Also, helicopters generally cruise at lower altitudes than airplanes and fly different routes. Thus several miles from an airport, helicopters may be the loudest aircraft around.



In general, aircraft noise impacts are greater below the takeoff paths than at the arrival end of the runway. These differences, though, depend both on the aircraft type and on the distance from the runway. For example, as depicted by the preceding illustration, at some distance from the runway, jets will have climbed high enough that they may produce much less noise on the ground than the slower climbing propeller airplanes. When landing, all jets and propeller planes follow about the same approach slopes, thus noise differences depend mostly on the aircraft size and engine types. Also, because engines are set to low power levels on approach, the noise produced by the airframe from such features as wing flap and extended landing gear may be greater than the engine noise.

Noise Contours

Noise contours are used to map or graphically depict areas of equal noise exposure around a noise source, such as an airport or highway. Just about any noise metric data can be illustrated in this manner. For land use compatibility planning purposes, though, noise contours are usually associated

with cumulative noise level metrics such as DNL (day-night level or L_{dn}). DNL contours are commonly shown at 5 decibel increments so that they resemble topographic contours.

These days, noise contours for civil airports are produced using an FAA-approved computer program: the Integrated Noise Model, known commonly as INM. Most of the data about the performance capabilities and noise generated by various types of aircraft are stored in the program. The user must enter data regarding the number of operations by each aircraft operating at the airport, the time of day when the operations occurred (day versus night), the runways used, and the flight tracks followed. INM is capable of taking into account the actual ground elevations around an airport, thus increasing the calculated noise levels where the terrain is high and aircraft are consequently flying at a lower altitude than would be the case with flat terrain.

For many airports, especially those with relatively little activity, noise and other impacts associated with aircraft overflight can be more significant than the noise described by DNL contours. See the discussion of nuisance noise in the next appendix C.

To get an idea of how big the noise contours are for some typical small airports, see the illustrations on the next page.

Preparation of noise contours showing current and projected airport noise impacts is generally done as part of an airport master plan and is usually a required component of environmental documents for airport expansion projects. For busy airports where significant noise impacts, as measured by DNL, extend well beyond the airport boundary, noise contours are an essential airport land use planning tool.

However, for many small airports, particularly those not eligible for Federal Aviation Administration funding, noise contours may never have been done. *This is not a fatal shortcoming to your compatibility planning process and does not mean that you must create noise contours for your airport.* Indeed, when an airport has a low volume of aircraft operations and little or no jet activity, the DNL contours might not extend far beyond the runways. In these situations, overflight impacts as discussed in the next appendix need to be weighed heavily in compatibility planning.

Approaches to Addressing Airport Noise Impacts

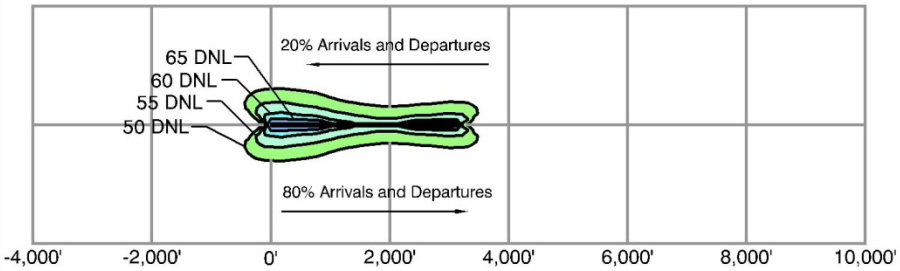
Acceptable Noise Exposure Levels

Noise impacts are a primary determinant of the acceptance of an airport in a community. Conversely, community planning for new development near airports must take into account the current and projected airport noise levels. The fundamental decision that local agencies will need to make in this regard is what exposure level is acceptable for new development, particularly residential and other noise-sensitive land uses. Your first thoughts on this topic may well be to simply adopt the criteria indicated by the FAA in its Federal Aviation Regulations Part 150, *Airport Noise Compatibility Planning Program*, and in other policies. In FAR Part 150, the FAA considers all uses compatible where the noise exposure is less than 65 dB DNL.

However, this is often not the best noise exposure threshold to use for compatibility planning purposes. Indeed, in other guidelines such as those for addressing the noise impacts of airport expansion, the FAA recognizes that noise impacts may be significant at levels below 65 dB DNL and should be considered depending upon the circumstances. Also, in the assurances that the FAA requires from airports receiving federal grants, the airport sponsor must agree to "take appropriate action, to the extent reasonable, including the adoption of zoning laws, to restrict the use of land adjacent to or in the immediate vicinity of the airport to activities and purposes compatible with normal airport operations."

General Assumptions

- Straight-in/straight-out flight tracks
- 3,200' Runway
- Airport elevation of 800'
- 85° F is average high temperature for hottest month
- 80% of single-engine piston operations are fixed pitch
- 20% of single-engine piston operations are variable pitch
- 80%-20% runway use distribution

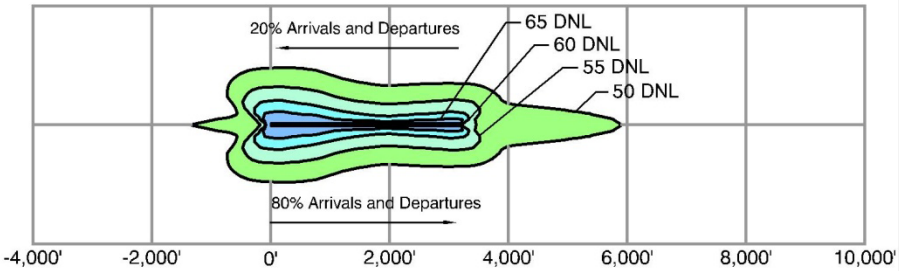


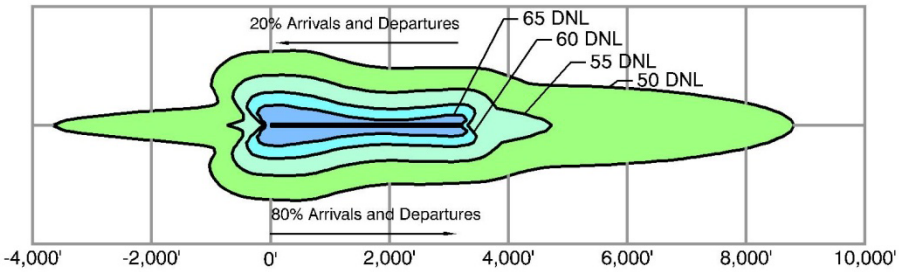
3,000 Annual Operations

- 100% Daytime
- 100% Single Engine Piston

10,000 Annual Operations

- 99% Daytime
- 1% Night Time
- 96% Single Engine Piston
- 3% Twin-Engine Piston
- 1% Light Turbo Prop





20,000 Annual Operations

- 98% Daytime
- 2% Night Time
- 93% Single Engine Piston
- 5% Twin-Engine Piston
- 2% Light Turbo Prop

Generic Noise Contours for Typical Small Airports

Several facts about the basis for the 65 dB DNL standard are important to recognize:

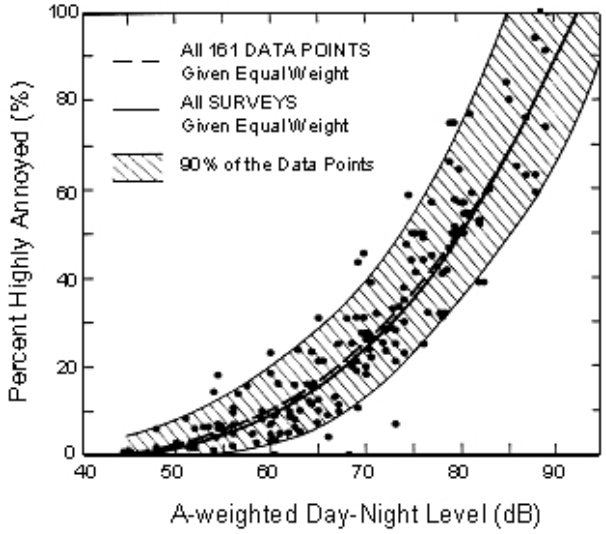
- The underlying sociological studies date back more than 30 years. Chief among these was one done by Schultz in 1978 which itself was a compilation of prior studies. One product of this study was the so-called "Schultz curve." This curve shows that 13% of the population living near an airport can be expected to be highly annoyed when the noise exposure is 65 dB DNL. Presumably, the percentage of people who are moderately annoyed would be even higher.
- The studies involved major air carrier airports in noisy urban environments. The degree to which people in quieter communities would be annoyed at lower noise exposures was not studied.
- Even though the loudness of individual jet aircraft operations has been significantly reduced since the 1970s, people continue to be bothered by the noise. This may be due to an increase in the number of operations or simply because people's expectations regarding quiet are greater.
- Compatibility does not mean that activities will not be disrupted by individual noise events. Even cumulative noise exposures of 60 or 55 dB DNL can include individual loud events that may be disruptive.
- The FAA's use of the 65 dB DNL as the threshold of environmental impact significance for noise impacts was and largely continues to be driven by economics. Airports can obtain FAA funding to install sound attenuation in homes and other noise-sensitive uses exposed to noise levels of 65 dB DNL or greater. Reducing the standard to a lower noise exposure level would vastly increase the number of buildings eligible and the costs would be large.

To reiterate, the prominence of the 65 dB DNL standard notwithstanding, FAA policy does not preclude local jurisdictions from setting a lower threshold of compatibility for new land use development. The FAA's Aviation Noise Abatement Policy 2000 states:

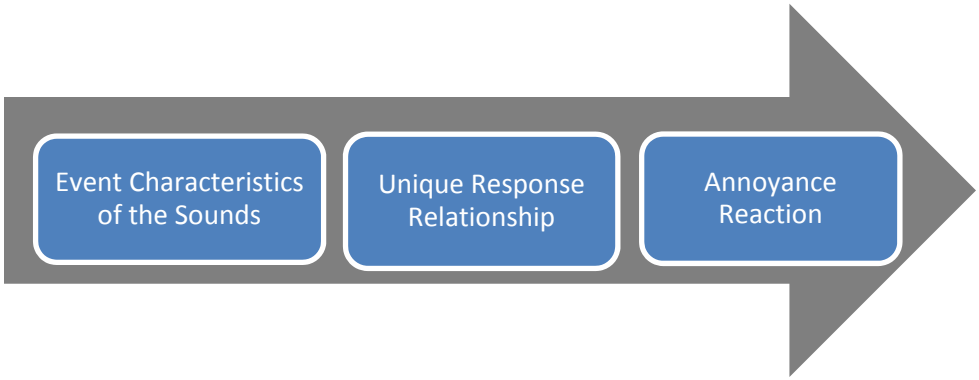
> "Based upon local factors, local jurisdictions may take a more comprehensive approach to aviation noise exposure below DNL 65. Some communities are more noise sensitive than others. Part 150 guidelines recognize local discretion to define noise sensitivity."

WSDOT encourages communities to seriously examine the significance of nuisance noise, noise impacts at levels below 65 dB DNL, along with the single-event noise levels, vibration, odors, annoyance, and other impacts of regular aircraft overflights—and to avoid new development that might be incompatible with these noise levels. The affects of aircraft nuisance noise and the annoyance associated with it, as addressed in the appendix C, should be considered as well.

The Schultz Curve and Modal Noise Bias



The 65 DNL threshold relies upon the Shultz Curve to identify a level of compatible noise. This is an imperfect approach, since the Shultz Curve fails to take into account the different transportation noise sources, such as road, rail and aircraft. The relationship between different modes and their noise impacts has been described as the exposure-response relationship (Girvin). Empirical evidence suggests that like rail noise, aircraft noise has a unique exposure-response relationship attached to it (Girvin). Simply put, people generally have a predisposition to be biased against aircraft noise. This is sometimes referred to as modal bias. What differentiates aircraft and rail noise from road noise is the event characteristics of the sound (Hoeger), which affects an individual's annoyance reaction (Hoeger). Aircraft noise is mainly characterized by single events, while road traffic noise is perceived as more or less continuous (Hoeger). Some people also view the sporadic nature of aircraft operations as more obtrusive noise events when compared to other modes, especially when they disrupt intended activities (Hoeger). Aircraft noise can be particularly intrusive during warmer weather when people are outside more or when residents leave their windows open. Research shows aircraft noise to be more annoying during the night or early morning hours, when ambient noise levels are lower and people are normally sleeping. These intrusive noise events can lead to negative evaluations of the airport, and the noise source can be seen as a highly unpleasant nuisance within the community (Hoeger). Psychological and social conditions are other Other considerations associated with the 65 DNL threshold and the Schultz Curve include:



- The 65 DNL noise contours fail to explore the relationship and interaction between aircraft operations and the community. For example, many airports experience the majority of their operations during VFR conditions. Since outdoor activity is a significant aspect of single family residential development and often takes place during periods of good weather, the two activities often take place simultaneously.

- One weakness of the 65 DNL contour is that it is a prediction, and it's only as good as the forecast and other input assumptions, e.g., flight tracks, fleet mix, etc.
- The studies involved major air carrier airports in noisy urban environments.

Noise Insulation

The mass of buildings' structural components greatly reduces the amount of aircraft noise heard indoors compared to outside. Modern, energy efficient, wood frame buildings typically reduce the exterior to interior noise levels by as much as 30 dB when windows are closed. Even with windows open, other parts of the structure can serve to substantially reduce the indoor sound levels caused by exterior noise.

Heavier structures, such as ones with concrete walls, or buildings designed with added noise insulation features can further enhance the noise level reduction. These qualities have often led to the view that aircraft noise impacts do not need to be a deciding factor in siting of noise-sensitive land uses near airports provided that adequate sound insulation is incorporated into the building design.

Noise insulation should not be thought about in this manner. *The most appropriate application for structural noise insulation is for existing buildings.* It is a method of improving existing incompatible conditions when changing the land use to something less noise sensitive is not practical. Even then, there are limitations. *Noise insulation is not effective for land uses in which noise-sensitive activities take place outdoors.* Unlike the case with ground-based noise sources, sound walls and other such devices do nothing to block noise from aircraft while they are in the air.

With regard to new development, noise insulation should be regarded as a measure of last resort. It is not a substitute for good land use compatibility planning in the first place. Exterior noise levels should generally be the primary consideration in evaluation of proposed land uses, especially residential development and other land uses where noise-sensitive outdoor activities are normal and important features.

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