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.

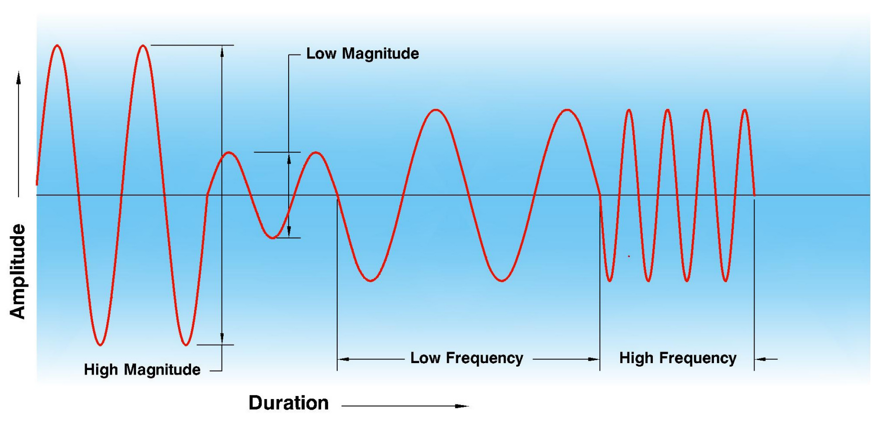
- **Magnitude** – Magnitude is a measure of the strength or amount of acoustic energy carried by a sound wave. Because the energy level of sounds we can hear varies in magnitude by a factor of 1 to 100 trillion—that is 10^{14} or 1 followed by 14 zeros—we measure magnitude using a logarithmic scale rather 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. 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 trade-offs between noise levels, fuel efficiency, and the amount of emissions produced.

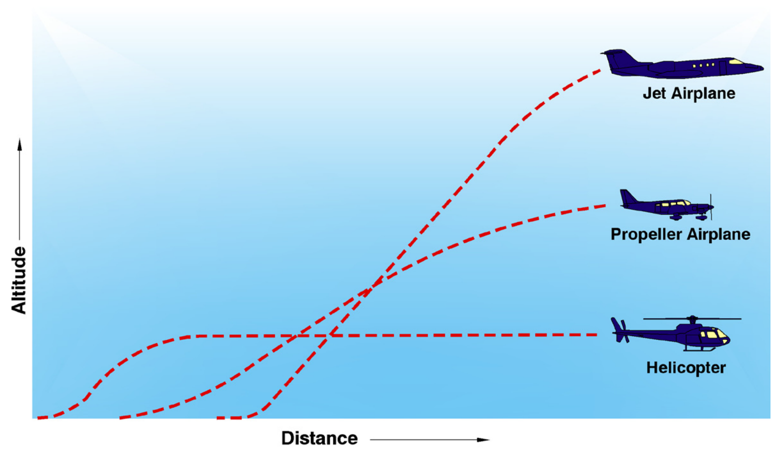
Courtesy of Cessna

- **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.

Courtesy of Cessna

- **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. These pulsations are a key to understanding the greater annoyance that results from a helicopter flyby. Helicopter noise during the measurement process takes a highly variable source noise and averages it. In reality, people respond to the peaks which are audible at great distances as the onset and end point for the noise event. The result is a much longer total duration event. This contributes to a disproportionately adverse response. The noise is greatest during high-speed cruise and low-speed descents.

Typical Takeoff Profiles



The amount of noise generated by different aircraft types is only one factor affecting how much noise is heard on the ground. Atmospheric conditions can make the sound bounce back to the ground and 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

For many airports, especially those with relatively little activity, noise and other impacts associated with aircraft overflight can be aggravating and viewed as more obtrusive due to their apparently random occurrence.

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.

Preparation of noise contours showing current and projected airport noise impacts is generally done for larger airports 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 may be generated beyond the airport boundary, noise contours, as measured by DNL may be generated as a planning tool to address compatibility. However, for most airports in Washington State, particularly those not eligible for Federal Aviation Administration funding, identifying noise contours is not necessary because aircraft noise levels do not generally exceed the 65 DNL threshold beyond the airport property. The 65 DNL threshold is used by the FAA to assist in determining eligibility for federally-funded noise mitigation programs. See Federal Aviation Regulations (FAR) Part 150 “Noise Compatibility Program” for more information.

Approaches to Addressing Airport Noise Impacts

Sitting Appropriate Uses

The FAA recommends that local jurisdictions address noise sensitive land uses through their development regulations by taking steps to understand airport operations and aircraft noise issues so that they can take steps to minimize noise impacts. Noise impacts are one of the factors that can be considered by local jurisdictions when developing strategies for addressing compatibility near airports. As indicated above, noise can be measured in terms of magnitude, how loud; frequency, how often; and duration, how long. Each of these factors, together with other compatibility criteria addressed in these guidelines can assist local jurisdictions in determining what strategies or criteria should be used in locating different types of land uses near airports. For example, some land uses such as a storage facility or restaurant may be located almost anywhere near an airport, however, locating a restaurant near the end of the runway may degrade the atmosphere for restaurant customers due to noise and increased accident risk levels. Whereas storage facilities have fewer customers with different expectations. The fundamental questions that local jurisdictions will need to address are:

1. What is the function of the proposed land use activity.
2. What connects the land use activity to the location.
3. What factors should be considered to ensure sustainability.
4. How will the land use activity be impacted by its environment.
5. What other factors are necessary to maintain a high quality environment.

WSDOT's guiding principal of "do no more harm" should always be exercised when considering what type of uses or activities should be promoted within the airports influence area without degrading the operational capabilities of the airport and the proposed activity.

> State and local governments may protect their citizenry from aviation noise through land use controls and other police power not affecting airspace management or aircraft operations- FAA

Individuals and community responses to aircraft noise differ substantially and, for some individuals, a reduced level of noise may not eliminate the annoyance or irritation. The FAA address land use compatibility primary through grant assurances. In the assurances, the FAA requires that airports receiving federal grants, "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."

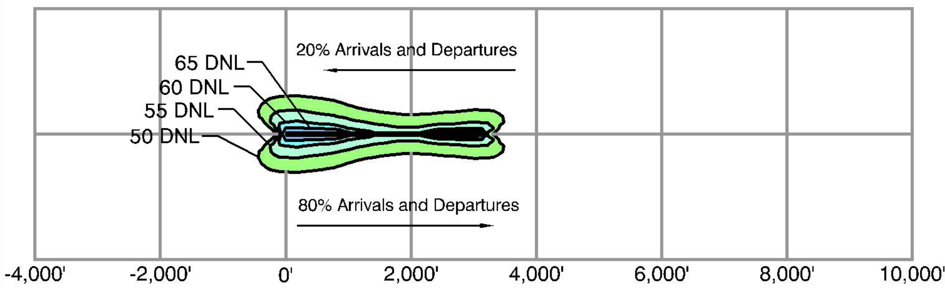
Several facts about current standards and noise contours are important to recognize:

- 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.
- Noise contours fail to fully 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.
- 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.
- Noise contours are a prediction, and it's only as good as the forecast and other input assumptions, e.g., flight tracks, fleet mix, etc.
- DNL is based on a year-long average and therefore may not reflect seasonal adjustments or increase aircraft operations or frequency during peak hour events

Generic Noise Contours for Typical Small Airports

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

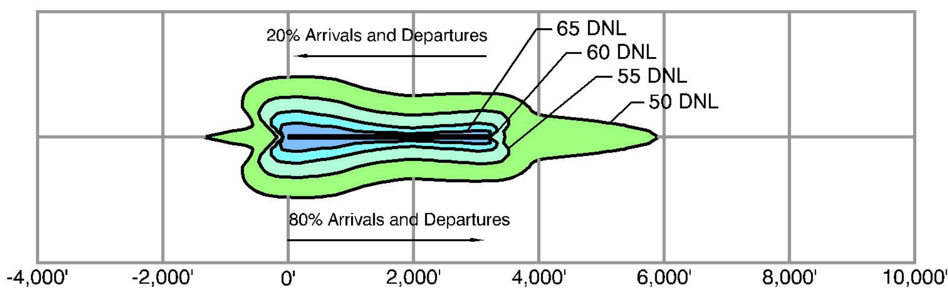


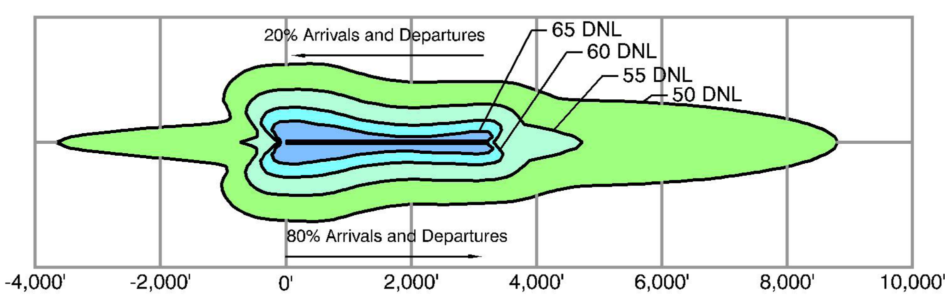
3,000 Annual Operations

- 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

Source: Mead and Hunt

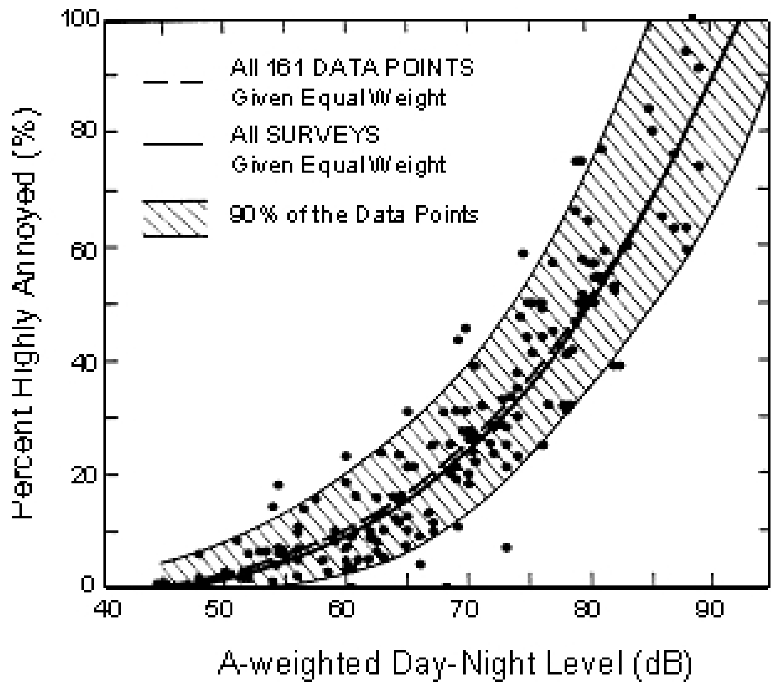
To reiterate, the FAA policy does not preclude local jurisdictions from setting a lower threshold of compatibility for new land use development. In fact, some states like Oregon have passed legislation that requires airports to analyze lower noise level thresholds. The FAA's Aviation Noise Abatement Policy 2000 states:

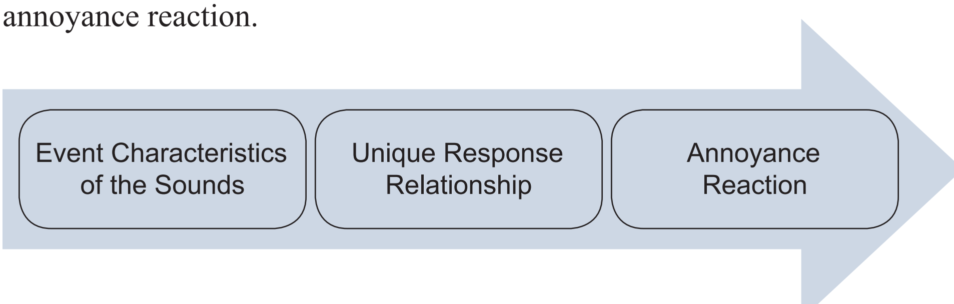
> "Based upon local factors, local jurisdictions may take a more comprehensive approach to aviation noise exposure below DNL 65. Some communities are more noise sensitive than others. Part 150 guidelines recognize local discretion to define noise sensitivity."

WSDOT encourages communities to seriously examine the significance of noise impacts, along with other compatibility factors such single-event noise levels, low flying aircraft, vibration, odors, annoyance, and other impacts of regular aircraft overflights—and to avoid new development that might be incompatible within the airport influence area. The affects of aircraft noise and other annoyance associated with normal airport opperations, as addressed in the appendix C, should be considered as well.

The Schultz Curve

The 65 DNL threshold addressed by the FAA through Federal Aviation Regulations (FAR) Part 150 in part relies on information derived from the Shultz Curve. The Shultz Curve was used to identify a level of compatible noise. Like many metrics, the Shultz Curve has its limitations. The curve is based on 30 year old sociological studies. Although cutting edge at the time, the studies failed to address a variety of variables. The Schultz curve is derived from aircraft, rail and transportation noise. The relationship between different modes and their noise impacts has been described as the exposure-response relationship[1]. Empirical evidence suggests that like rail noise, aircraft noise has a unique exposure-response relationship attached to it. This is due to event characteristics of the sound), which affects an individual's annoyance reaction.





[1] Hoeger, et al.

Aircraft noise has generally higher amplitude at the peak and is broadcast over wide areas from above. Simply put, one cannot simply go into the backyard and escape it. Aircraft noise has a sudden onset and may produce a fear response and an unusually loud aircraft noise implies that the airplane is close by accentuating the fear response.

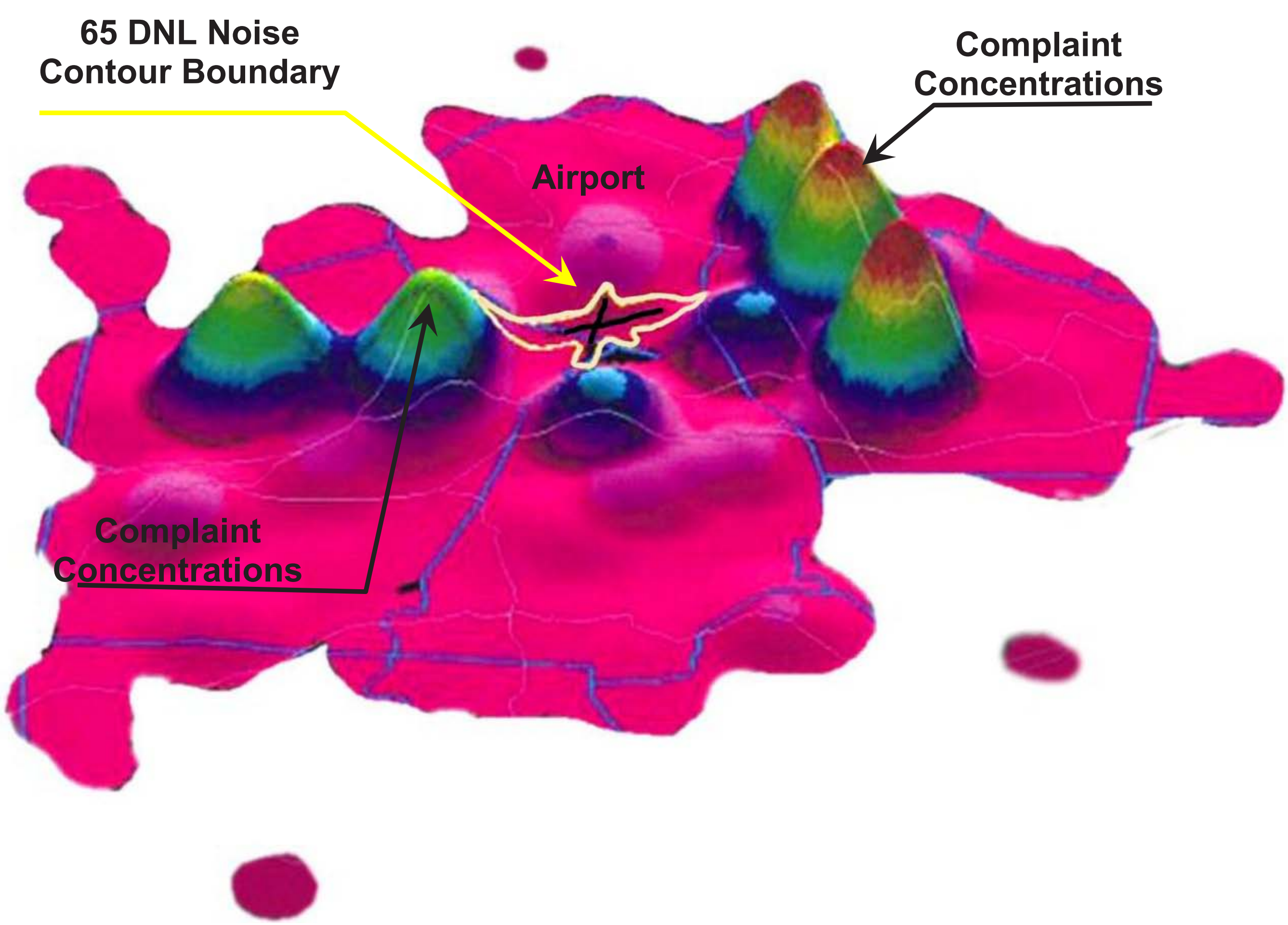
Single noise events, especially in areas where the background noise level is very low, contributing disproportionately to adverse responses.

Additionally, aircraft noise is mainly characterized by single events, while road traffic noise is perceived as more or less continuous[2]. Some people also view the sporadic nature of aircraft operations as more intrusive noise events when compared to other modes, especially when they disrupt intended activities[2]. 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[2]. Other considerations associated with the Schultz Curve include:

- 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 Schultz curve is derived from aircraft, rail and transportation noise. Adverse reactions are greatest for aircraft, then road vehicles and finally rail. Averaging these three sources together underestimates the level of impact from aircraft.
- 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.
- But the time the noise surveys were conducted, truly noise sensitive individuals had relocated out of the sample population. This often referred to as a "survivor population". Thus the responses collected by the studies did not reflect the population as a whole.

[2] Night-time Noise Annoyance: State of the Art, Hoeger, et al.

Case Study: Hanscom Field GIS Noise Analysis



Source: The Schultz curve 25 years later: A research perspective

Complaints were geo-coded into street addresses and then spatially modeled in GIS. Complaints are represented by the graduated colors and vertical extrusion. The spatial analysis demonstrates that complaint concentrations are well beyond the airport's 65 DNL cumulative noise exposure contour.

Complaints are represented by the graduated colors and vertical extrusion (exaggeration).

65 DNL Noise Contour Line - yellow polygon

Airport runways -black intersecting lines

The argument that single event noise is a substantial compatibility factor is supported by research regarding the spatial distribution of noise complaints at Naples Municipal Airport , Hanscom Field and San Francisco International Airport. The research shows that most aircraft noise complaints are received from geographic areas outside traditional noise exposure contours. This fact demonstrates that noise complaints often have more to do with fleet mix, event times and operational characteristics than projected noise contours. Cumulative noise exposure is itself a far from perfect predictor of annoyance

Aircraft noise is very similar to noise generated from common power tools. It is loud enough to be intrusive, disruptive and cause conflict between neighbors. Single event noise characteristics and the high visibility of aircraft operations intensify the negative response many individuals experience.

String Trimmer

Aircraft Operations

Chainsaw

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 and does not address a local jurisdictions responsibility to discourage incompatible development adjacent to the airport. 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.