Helicopter Noise: What is the Problem?

By Dr. John W. Leverton

The Issue

Helicopter operations around the world, and in particular in the United States, are giving rise to objections over noise from the general public; in the last two or three years there have been major objections to helicopter use in the New York and Los Angeles areas. The development of new heliports, and changes to services at existing facilities, tend to be controversial and are often rejected as a result of public opposition. Such negative response to helicopter operations as a result of noise is a little difficult to understand because most helicopters generate less noise than the noise certification standards and, in most cases, meet established community noise rating criteria and guidelines. Also, the same rating methods are generally considered to be successful in understanding the environmental impact of large commercial aircraft and other forms of transportation, so there appears to be something different about the way in which helicopters are perceived. Even so, the issue of helicopter noise in connection with heliport operation is continually being reported in the aviation and general press. This issue has also been addressed in a report on non-military helicopter noise issued to the US Congress by the Federal Aviation Administration (December 2004) and for the UK Department for Environment, Food and Rural Affairs (Defra) in a June 2008 study (see **www.vtol.org/noise** for the reports).

Social Surveys

A review of case histories, press reports and information collected by industry associations makes it clear that helicopters and heliports, in many locations, have only a low level of public acceptance. This was put into perspective a number of years ago when the results from a number of studies connected with the operation of helicopters in the United Kingdom was reported in 1993 by the UK Civil Aviation Authority (CAA). The CAA results are given in Figure 1 and shows annoyance as a function of the noise levels expressed in terms of "L_{Aeq} (16 hr)" – effectively the average sound level over a specified time.*

Data from the 1982 survey indicated on the figure were obtained by the CAA along the route of the Gatwick-Heathrow Airlink service (no longer operating) and at Aberdeen, Scotland, the major base for offshore oil industry helicopter operations in the North Sea. This data reveals that helicopters operating in the London area are considered to be up to 15 dB(A) more annoying than fixed-wing aircraft. This result contrasts with that obtained in Aberdeen which shows helicopters to be no more annoying than fixed-wing aircraft. In both cases, the characteristics of the acoustic environment were influenced by large, acoustically non-impulsive helicopters.

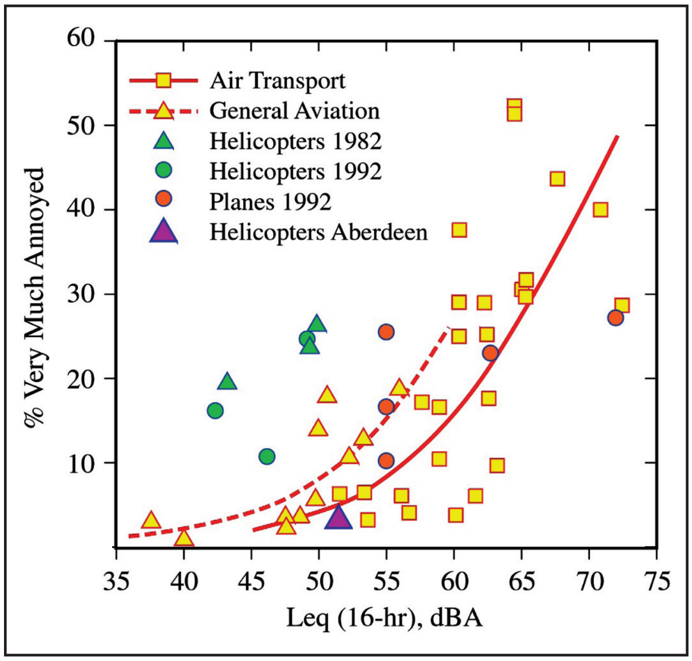

Figure 1: UK CAA Social Survey Results (1993)

One prominent researcher at the time suggested this disparity in reaction between London and Aberdeen could be explained in socio-economic terms: "Better off people tend to be more annoyed." In addition, residents under the Airlink flight path were less favorably disposed towards the helicopter shuttle service which was being used by first class passenger, whilst in the Aberdeen area, North Sea oil operations contribute significantly to the local economy.

In a small-scale 1992 study in London the results were similar to those for the Gatwick-Heathrow Airlink evaluated 10 years earlier. The London flights were dominated by the corporate market using light/medium helicopters, including a large number of Bell JetRangers and LongRangers plus Aerospatiale (now Airbus Helicopters) Dauphins, Sikorsky S-76s and a few larger helicopters. Studies carried out by the Greater London Council in the same timeframe indicated an underlying concern of the residents about noise and safety of helicopters, which up until that time was not well documented.

The conclusion reached by many observers, who generally ignored the Aberdeen result, was that for a similar level of annoyance or acceptance, helicopter noise levels need to be much lower than those of fixed-wing aircraft and other forms

* L_{Aeq} (16 hr) expresses time-varying A-weighted (filtering sounds to mimic the response of the human ear) noise levels occurring during an observation period as a single constant value having the same acoustic energy. The 16 hour period from 7:00 a.m. to 11:00 p.m. is used in the UK. This metric is similar to the Day-Night Average Level (DNL or L_{DN}) metric used in the United States.

of transportation. The author does not support this point of view.

Public Acceptance

Community noise rating procedures are considered to predict relatively well the impact of fixed-wing aircraft noise around airports and within local communities during overflight. This is not the case for helicopters and heliports, which appear to create a level of adverse reaction disproportionate to the measured and predicted noise levels. A partial explanation for the disparity between noise assessments and community reaction to helicopter operations has been identified as deficiencies in the rating methods. For a more complete analysis of the issues, it is necessary to examine the way in which helicopter operations are perceived.

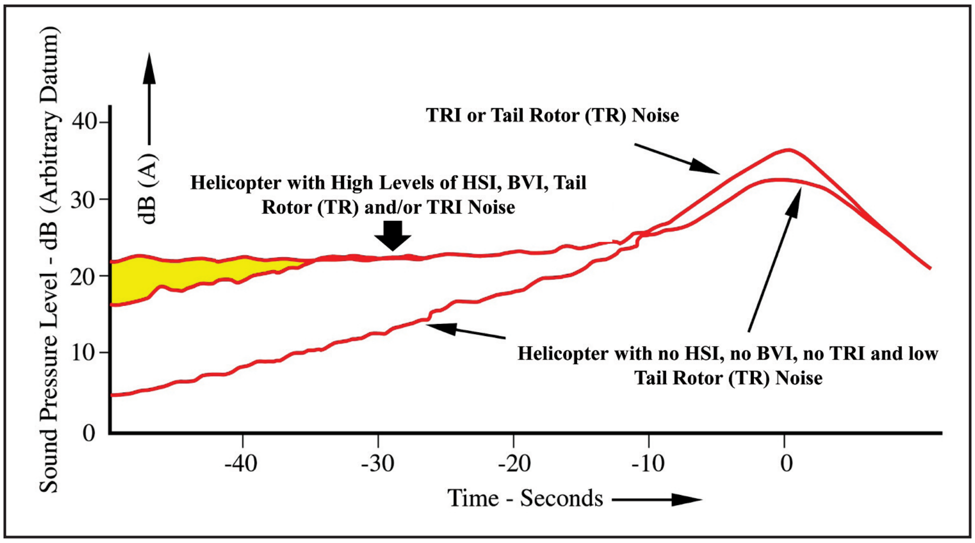

Figure 2: Generalized dB(A) Flyover Time History

Fixed-wing aircraft operations at airports typically involve a large number of flights per day and, because the noise characteristics of most of the large jets are similar to one another, the noise climate is relatively uniform. Away from airports, aircraft fly at very high altitude so that noise levels on the ground are low. In addition, there is little concern over aircraft safety. Helicopter operations are very different. In general, the paths, unlike those used by fixed-wing aircraft, vary widely and so at any one location the noise pattern is much less consistent. **There are also very large differences in both level and, more importantly, the character of noise created by different helicopters with some small helicopters sounding noisier than larger ones.** Overflights are generally made at relatively low altitudes so that any concerns over safety are heightened.

In the context of public acceptance, it should be noted that even relatively sophisticated noise rating methods based on complex objective measurements fail to account for the disturbance caused by helicopters and it has been (and is being) suggested that the noise certification limits and the criteria associated with community rating procedures should be made more stringent. Although minor adjustments to the assessment criteria may be helpful, analysis of the issues indicate that such action will have little or no direct effect on the level of public acceptance. For example, a comprehensive study of helicopter operations at a military airbase in the UK in 2000 concluded that **there was no meaningful correlation between helicopter noise levels and subjective annoyance.**

Helicopter Noise Characteristics

A generalized A-weighted sound pressure level time history of a helicopter flyover is shown in Figure 2 to illustrate the influence of various helicopter noise sources on overall noise level. The principal sources are main rotor thickness/high speed impulsive (HSI) noise, main rotor blade/blade vortex interaction (BVI) noise, main rotor wake/tail rotor interaction (TRI) noise and tail rotor (TR) noise. HSI, TRI and TR noise are most pronounced during flyover. BVI noise is normally the dominant source during descent, although TR and TRI noise may also be present. BVI can also occur on some helicopters during flyover/cruise flight and is pronounced during banked turns. In the case of tandem rotor aircraft, BVI occurs continuously, regardless of flight condition.

Measured in conventional subjective units, the form of the dB(A) time history will be similar to that indicated in the figure whichever of the sources dominant. Moreover, because all of the principal sources generate similar absolute noise levels, there will be little change in the time history even if one or two of the sources is pronounced at the same time. The directional characteristics of HSI and BVI are such that these sources have little influence on the maximum noise level which normally occurs close to the overhead position. Although TRI and high levels of tail rotor (TR) noise can increase the maximum level by up to 5 dB(A), the effect of these sources is much greater – 10-15 dB(A) – at distance as the aircraft approaches as shown on Figure 2. Most importantly, it can be seen that **the greatest effect of the intrusive sources occurs more than 10 dB(A) below the maximum value, so they will have little or no influence on time integrated units such as Sound Exposure Level (SEL) and Effective Perceived Noise Level (EPNL).**

The idealized traces shown on Figure 2 represent flights during which the impulsive sources are generated continuously. However, these sources often occur intermittently, in which case the time history will exhibit relatively rapid increases and decreases in level. Helicopters operated close to a BVI or TRI threshold will be particularly sensitive to control inputs and the ambient temperature in which the helicopter is operating. These changes in noise level will be more marked on higher tip speed rotors simply because the sources are naturally more intense. From a subjective point of view, the intermittent generation of the intrusive sources is equally or more annoying than if the sound occurred continuously, and tends to draw immediate attention to the helicopter. This is important when considering annoyance.

Helicopter Noise – Subjective Impact

The subjective impression created by the impulsive noise sources are very important when considering public acceptance. Also, except in the case of tail rotor noise, the sources of interest are mainly detected at levels well before the so-called "10 dB down" point – the point on the

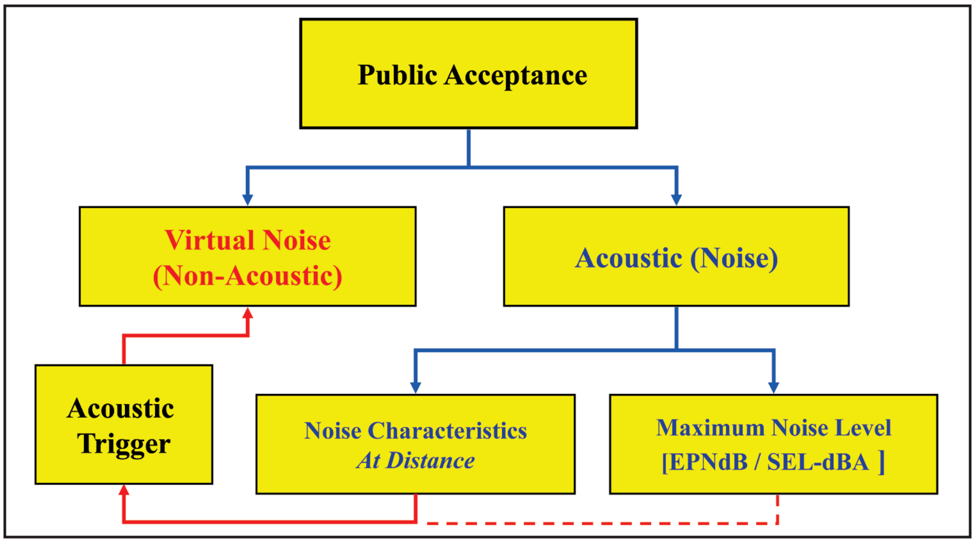

Figure 3: Elements of Public Acceptance

sound pressure level time-history at which the level is 10 dB below the maximum or peak level.

A study of the various factors involved shows the level of public acceptance can be considered to be a function of both acoustic (direct) noise and a non-acoustic element, termed virtual noise, as illustrated in Figure 3. The response to acoustic noise is a function of maximum noise level as defined by objective measurements and, more importantly in the context of public acceptance, the subjective characteristics of the noise as it first becomes audible. The magnitude of the non-acoustic component (virtual noise) is not related directly either to the absolute level or to the character of the noise generated by helicopters, but it is triggered by the direct acoustic signal.

The annoyance or level of public acceptance is usually quantified using measured noise levels as illustrated in Figure 1. Consequently, the virtual noise element is treated, for all practical purposes, in the same way as the direct acoustic energy (noise) radiated by the helicopter. Virtual noise is dependent on a wide range of inputs but is triggered initially by any distinctive feature of the acoustic signature and, to a far lesser extent, the absolute noise level.

It cannot be stressed highly enough that **whenever adverse reaction to helicopter operations results from virtual noise, attempts to address the problem by reducing acoustic noise at the source will be largely ineffectual.** It is not simply that the level of sound – at long range as the helicopter approaches or flies towards the observer – is higher than on helicopter models with little or no noticeable HSI, TR, TRI, or BVI noise. Rather it is that the tonal and impulsive characteristics of these sources are in themselves more annoying and draw attention to the helicopter.

Even though the influence of the characteristics of helicopter noise below the "10 dB down" point is clear to the author, many researchers continue to argue that EPNL – and by implication the SEL, LDN or LAeq metrics – give a realistic measure of both the source level and public response, implying that any increase in the sound associated with BVI, HSI, TRI and tail rotor noise is accounted for in full by metrics which take into account the duration.

The subjective rating of helicopter noise was investigated thoroughly in the late 1970s and early 1980s. One objective at the time was to develop an impulsive correction that could be added to more conventional metrics to account for the subjective effect of BVI and tail rotor noise. Despite the considerable effort expended, the results of these studies in combination were considered by many to be largely inconclusive. After an extensive review of all the issues, the International Civil Aviation Organization (ICAO) in 1983 adopted the EPNL for helicopter certification, with the proviso that **manufacturers should strive to eliminate intrusive noise sources.**

NASA studies on subjective response to helicopter sounds showed that the addition of an impulsive correction, which some had suggested, did not improve the human response predictions. While the case presented by NASA is valid, it is apparent that both the level and character of sound audible at distances greater than those involved in EPNL calculations, the author would suggest play a major part in the rating or acceptance of helicopter noise by the general public. It would appear that when the degree of BVI, HSI, TRI and/or tail rotor tonal noise is pronounced, these distinctive sources act as an audible cue, increasing the negative response to helicopter noise. These low absolute level triggers are not accounted for in EPNL or SEL calculations, which only account for acoustic energy within 10 dB of the maximum value.

The studies based on UK data, supplemented by information from other locations, including that associated with Airspur who operated in the Los Angeles, California area in the early 1980s, show that **the noise characteristics and virtual noise are of equal or even greater importance than the maximum noise level observed during a particular flyover or flyby event.** It is difficult to ascertain precise values for these components because they are partly interrelated. For example, a helicopter generating BVI or HSI noise may cause annoyance directly, while at the same time acting as a trigger to highlight public opposition by some other aspect of the operation. The information available also suggests that sounds such as tail rotor whine and/or main rotor impulsive noise (BVI or HSI) also exacerbate concerns over the safety of the helicopter because the sound may (falsely) suggest mechanical problems or conjure up an image of a helicopter crashing, as often seen in movies, television and online videos. Taking this argument to extremes, a helicopter generating low but perceivable levels of tonal or impulsive noise flying over an area where the public have major concerns on helicopter safety could create the same negative response as one with high levels of tail rotor, TRI, HSI or BVI noise operating over communities which are generally more tolerant of helicopters.

Subjective Considerations

Studies have shown that there is a need to consider the character as well as the absolute noise levels of sound heard by an observer. It is extremely difficult to quantify the effect on individuals of particular sounds in terms of a subjective weighting, but studies undertaken in the period 1975 - 1985 suggested values of 4 to 6 dB(A) and 6 to 9 dB(A) should be added to measured levels to account for signals with high levels of tail rotor noise and high levels of impulsive (BVI) noise, respectively.

When the helicopter noise and complaint information available was examined initially, a number of observations could not be explained. Further analysis showed that if an operation involves a mixture of helicopters with high levels of BVI, HSI, TRI and/or TR noise and those without such sources, the least acceptable will tend to dictate the level of public acceptance. **Thus a few noisy helicopters can create adverse response which will then affect the public response to all helicopters.**

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If, however, the number of operations of noisy helicopters is very low, this may not always be the case. In Aberdeen, Scotland one type of helicopter that generates high levels of impulsive noise (HSI and BVI) is known to provoke adverse public response. However, because of the small number of daily flights made by this aircraft and the careful selection of routes, it does not appear to detract from a generally acceptable level of public acceptance.

Concluding Remarks

The reaction to helicopters and heliports is dependent on several factors, some of which are completely unrelated to the absolute level of the helicopter noise. These non-acoustic phenomena described collectively as virtual noise are usually triggered by acoustic noise. The non-acoustic component can dictate the level of public response to helicopters under certain circumstances

The regulatory authorities, both nationally and internationally within ICAO, often argue that decreasing the absolute level of helicopter noise by lowering the noise certification limits or introducing operational noise limits, will dramatically improve the public acceptance of helicopters and solve most of today's objections to the level of noise generated by helicopters. The studies conducted by the author do not support this view. **The subjective character of the sound is equally or more important than the maximum noise level.** The sound quality of the noise at levels 20 dB or more below the maximum level provides the initial audible cues that alert an individual to the presence of a helicopter, i.e. provide the trigger for the virtual noise component. It follows that improvements to the noise signature by reducing or eliminating the impulsive sources will result in greater public acceptance irrespective of the absolute noise level generated. It also implies that many of today's small and medium size helicopters will need to fly at 2,000 – 4000 ft (600 – 1200 m) or more, and that the use of noise abatement procedures for normal operations are essential. Also, they will need to fly much slower than anticipated if impulsive noise is not to create a problem.

Designs to achieve a high degree of public acceptance should not be based only on achieving compliance with the noise certification limits. **It is also essential to take into account the sound pressure level and the subjective characteristics of noise throughout the period over which it is detectable, i.e. well outside the "10 dB down" range used to calculate EPNL and SEL.** This is particularly important if high tip speeds are being considered for the main and/or tail rotor.

Even so, there is certainly a need for more research into the subjective response to helicopter noise – the main activity in this area was over 20 years ago and there has been little examination of these aspects since then. From the industry point of view (operators and manufacturers) it is essential to establish what really needs to be done to improve public acceptance.

Analysis of the social survey results also reveals a strong connection between noise and safety, and that safety, or perceptions about safety, also play a significant part in public reaction towards helicopters which, of course, has a direct bearing on the level of acceptance.

US Customs and Border Protection AW139s patrol New York City. (CBP photo by James P. De Boer)

About the Author

John Leverton is the Environmental and Infrastructure Advisor for AHS International, with more than 45 years of experience in rotorcraft acoustics, environmental and infrastructure considerations. He is the president of Leverton Associates.

This article is based on papers published jointly by the author and A.C. (Tony) Pike, Acoustic Specialist, AgustaWestland, Yeovil, England, and additional papers published by the author during the period 1998 to 2009, plus studies by the author since that time. Key publications on noise studies – including a longer version of this study and other papers by the author – are available at **www.vtol.org/noise,** free of charge for AHS International members.